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THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

MAY 1961

THE PRODUCTION ENGINEER

VOL. 40 - NO. 5 PRICE 10/- MAY, 1961

CONTENTS

"MANAGEMENT OF MANAGERS" by J. D. Pearson, J.P., B.Sc.(Eng.), Wh.Sc., F.R.Ae.S., M.I.Mech.E., M.I.Prod.E. 309

Brighton Conference Paper
"PRESSURE ECONOMY" by Melvin D. Verson 314

Brighton Conference Paper
"PRESSURE FORGING OF STEEL SHAFTS" by Robert Speck, A.M.I.Prod.E. 321

Brighton Conference Paper
"THE FLUID-FORM PROCESS" by Hugh Möller 325

"DEVELOPMENTS IN DIMENSIONAL ACCURACY" by K. J. Hume, B.Sc., M.I.Mech.E., M.I.Prod.E. 336

"THE EFFECTIVE DIAMETER OF A PARALLEL SCREW THREAD" by L. W. Nickols, B.Sc.(Eng.), M.I.Mech.E., M.I.Prod.E. 344

"QUALITY ON THE SHOP FLOOR" by S. W. Nixon, M.Sc., M.I.Prod.E. 352

PERA NEWSLETTER 354

CORRESPONDENCE 355

MATERIALS HANDLING GROUP (LONDON SECTION) Report of Works Visit 358

COUNCIL NOMINATIONS, 1961 - 1962 361-2

NEWS OF MEMBERS 363

DIARY FOR 1961 364

HAZLETON MEMORIAL LIBRARY — Additions 364

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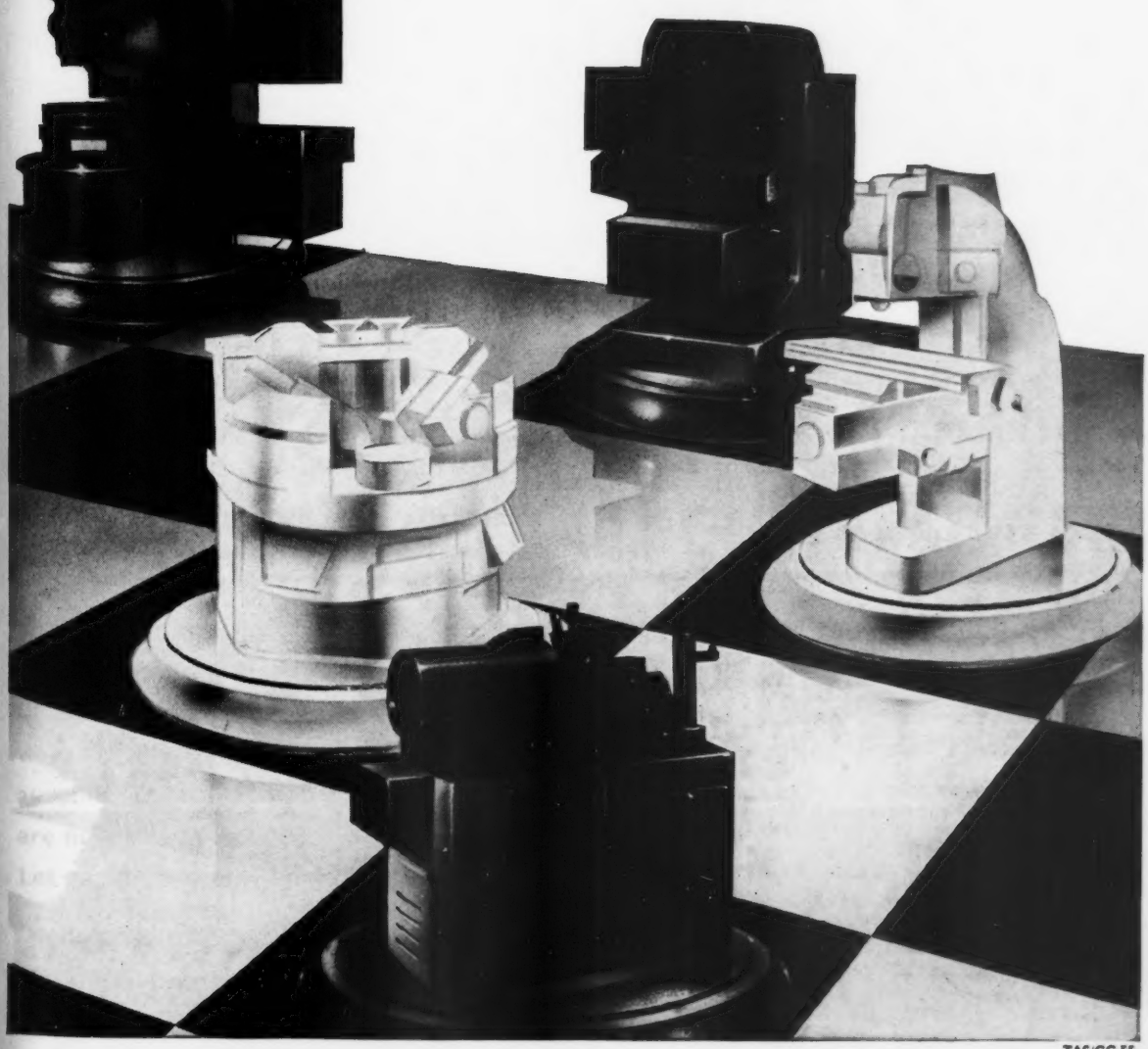

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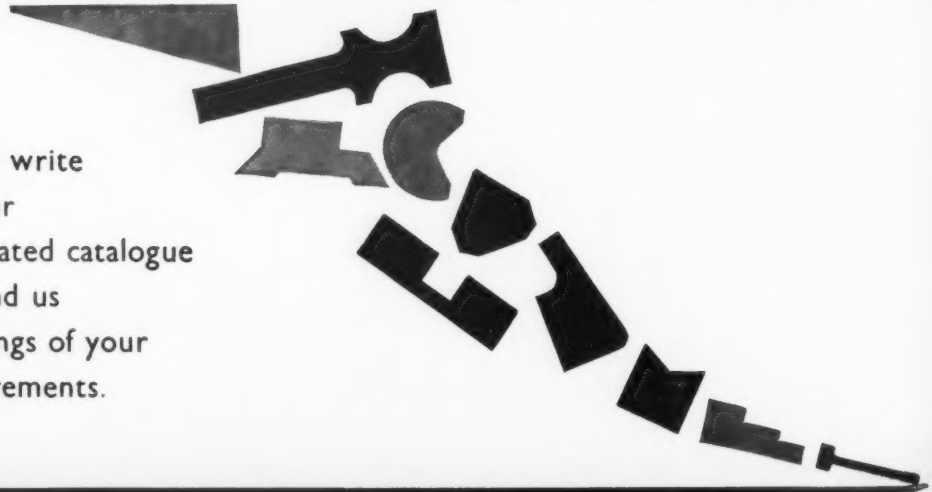

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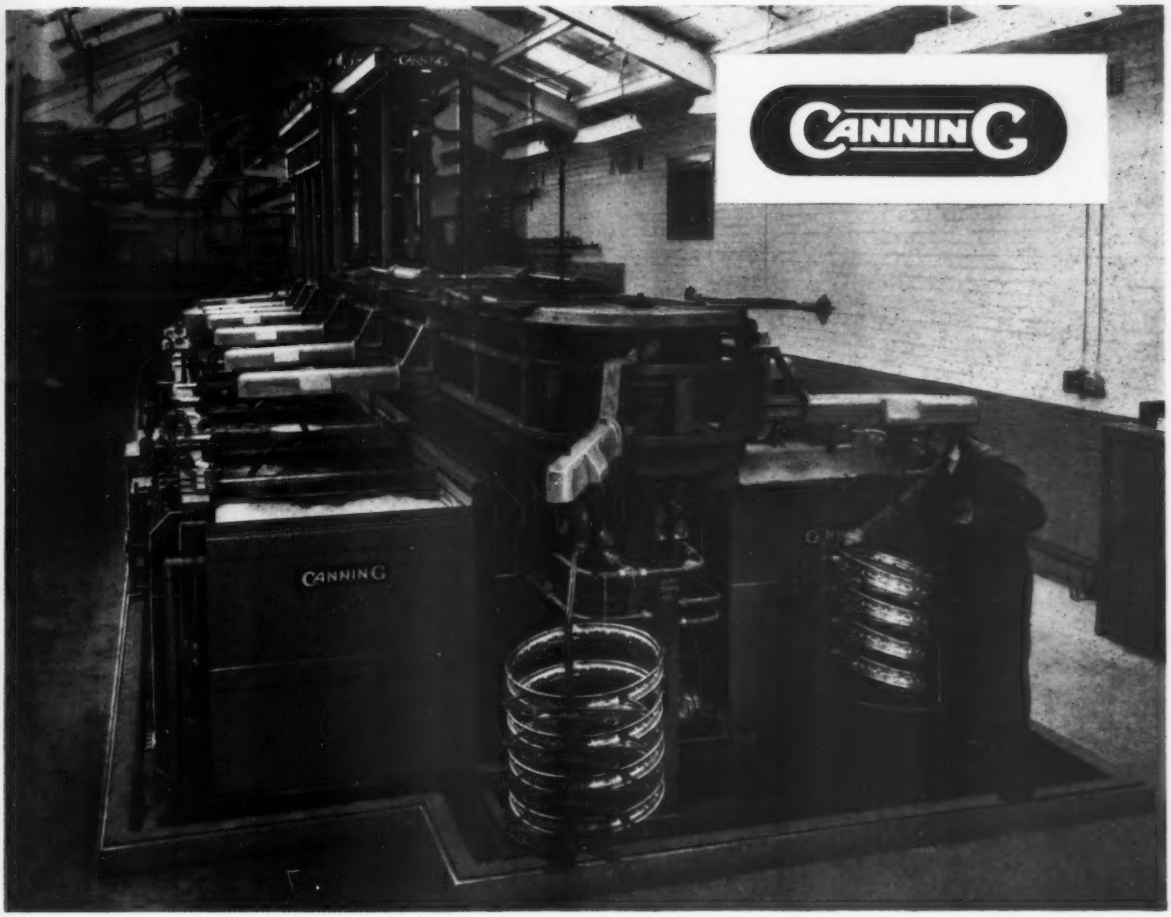

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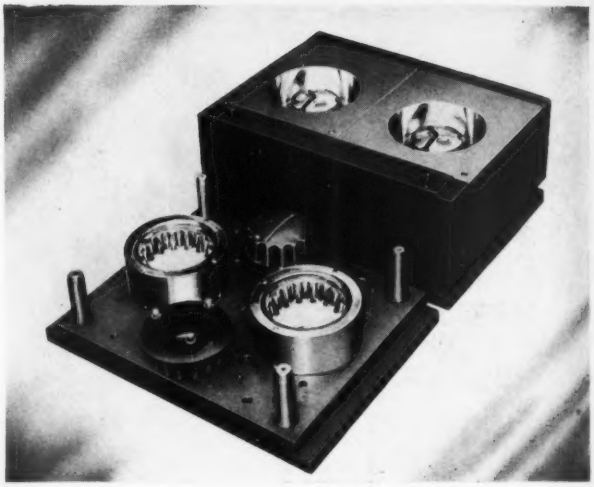

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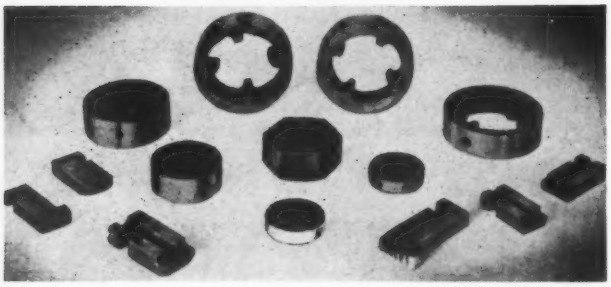

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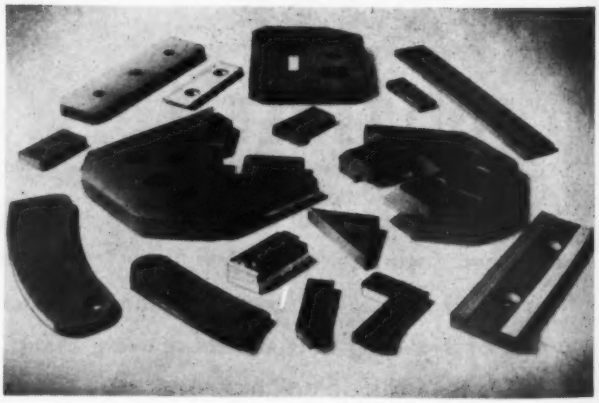

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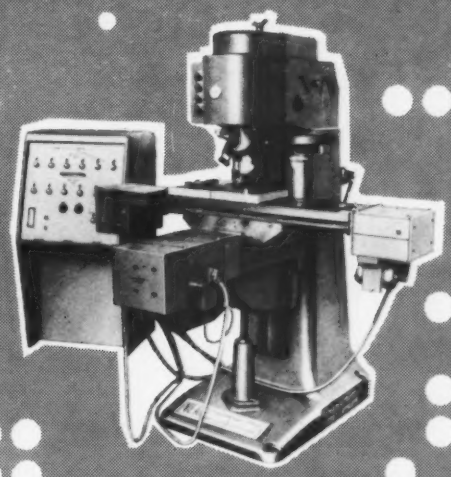

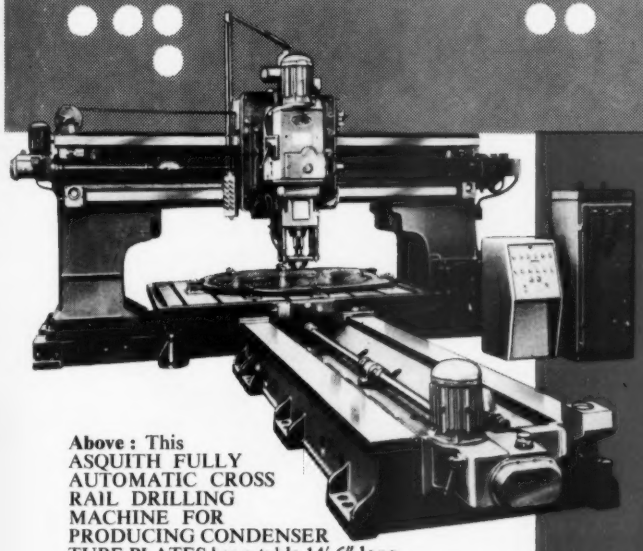

Above : This ASQUITH FULLY AUTOMATIC CROSS RAIL DRILLING MACHINE FOR PRODUCING CONDENSER TUBE PLATES has a table 14′ 6″ long ×10′ wide. Controlled by the AIRMEC AUTOSET, the overall accuracy of positioning is better than .005″. Manufacturer: William Asquith Ltd., Highroad Well Works, Halifax, Yorks.

Top right : Airmec Autoset fitted to Vero Auto-drill. 6 spindle Turret Head — 36″ × 9″ table. Spindle speeds 300 - 6,000 r.p.m. — $\frac{5}{16}$″ drill capacity. Manufacturer : Catmur Machine Tool Corporation Ltd., 103 Lancaster Road, London, W.11.

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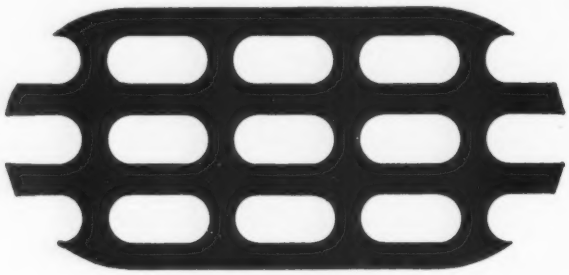

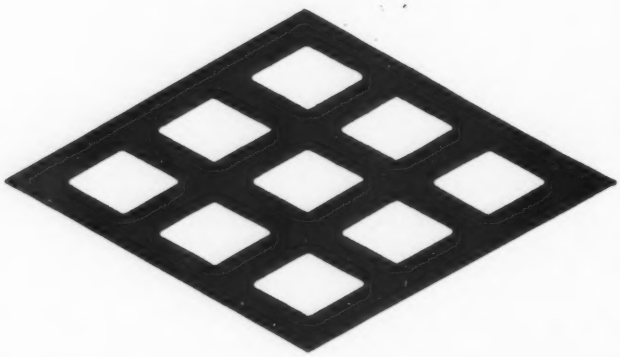

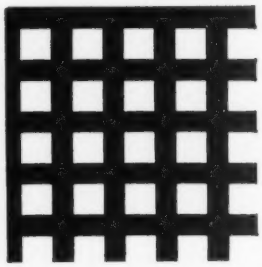

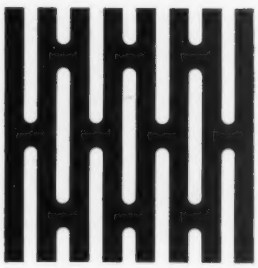

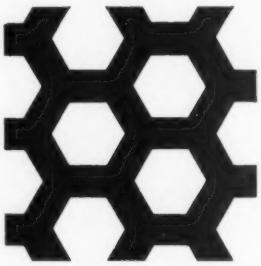

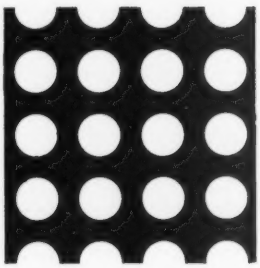

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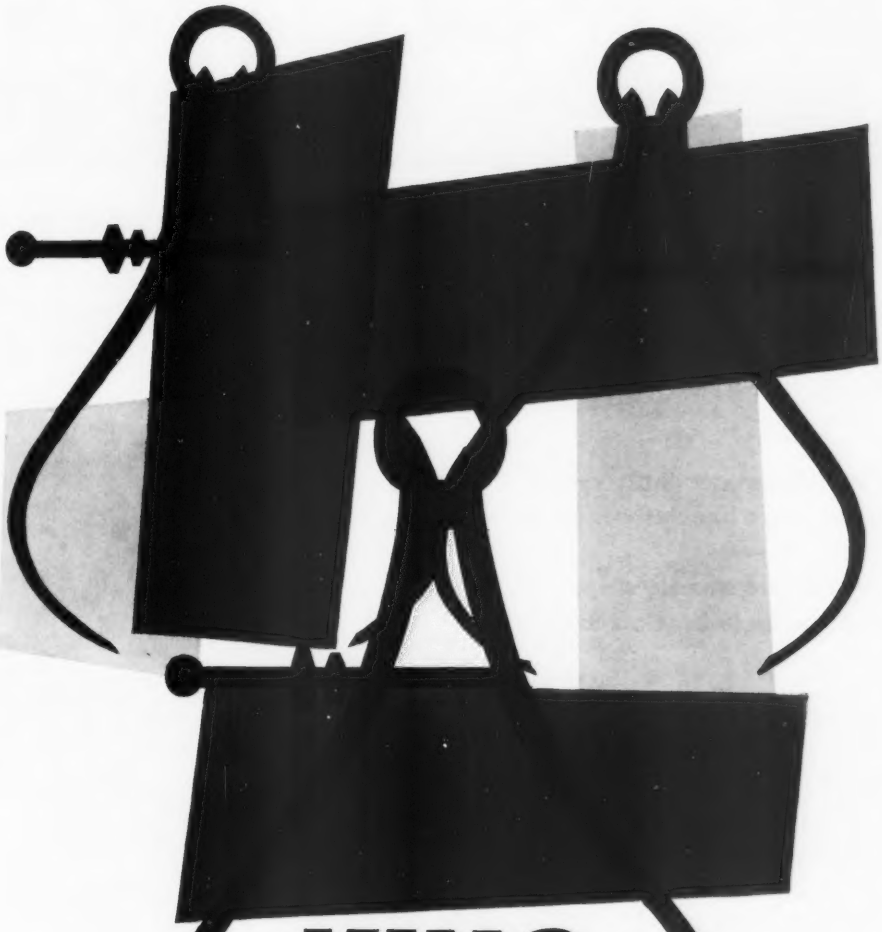

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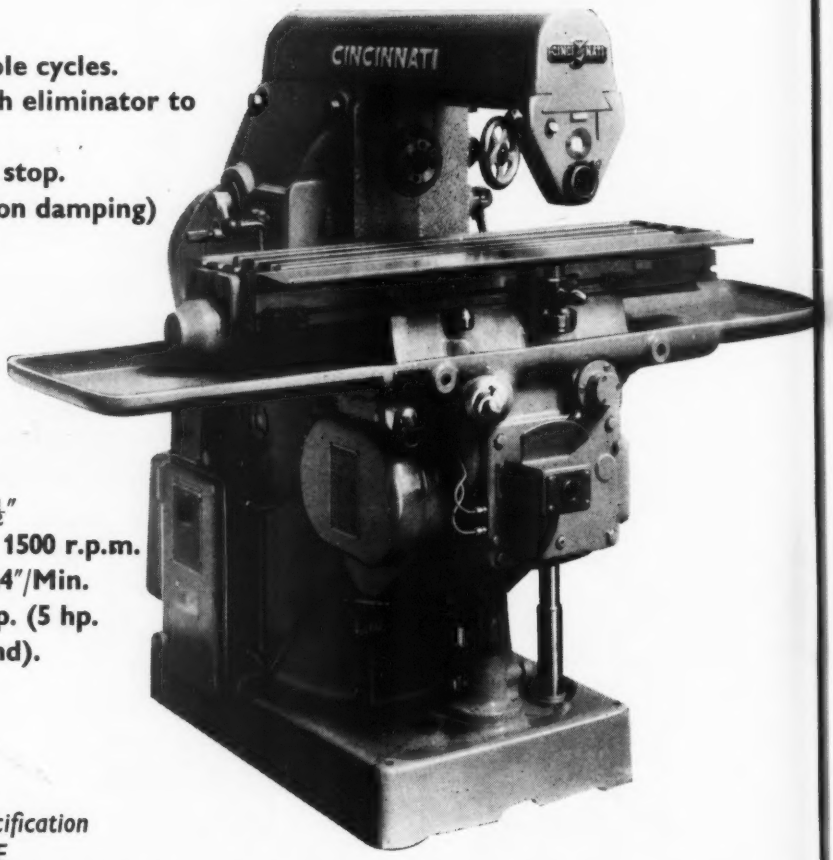

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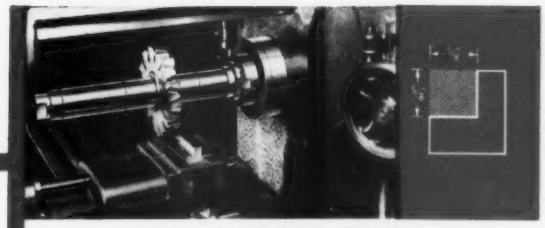

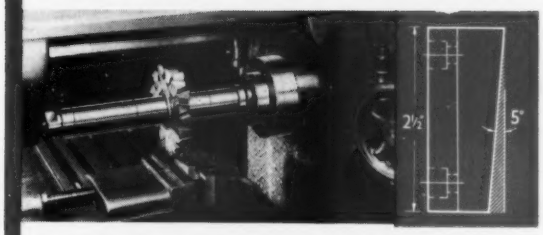

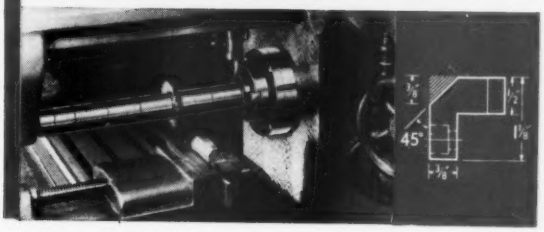

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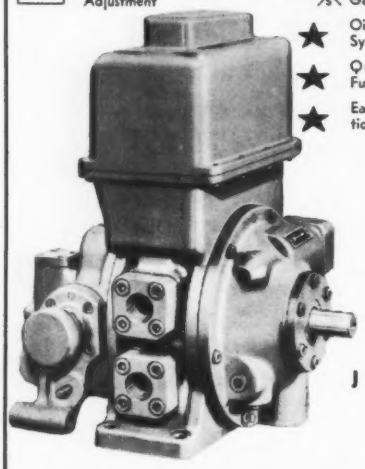

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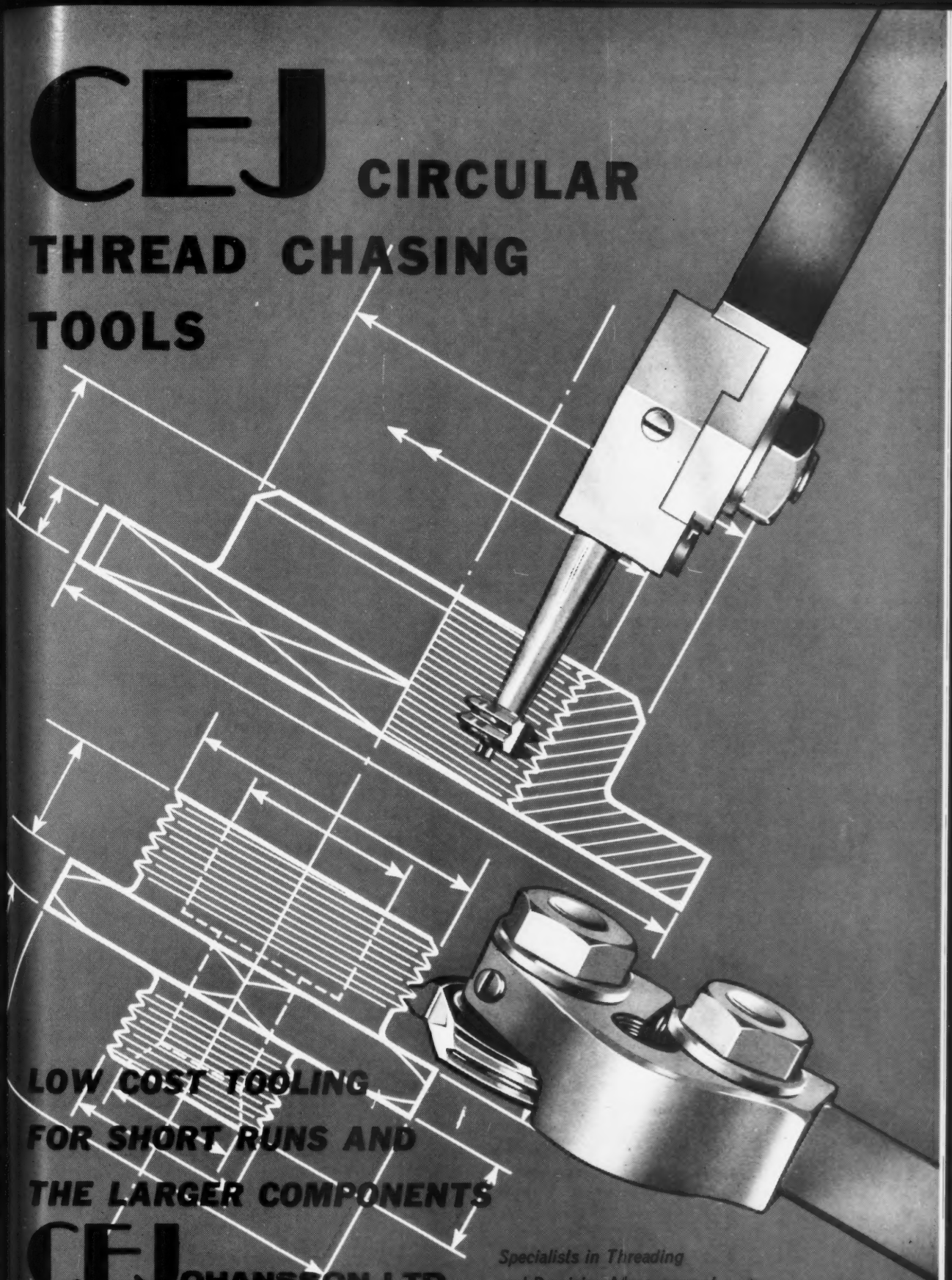

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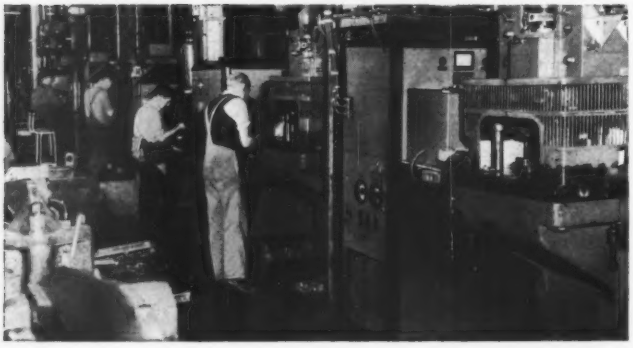

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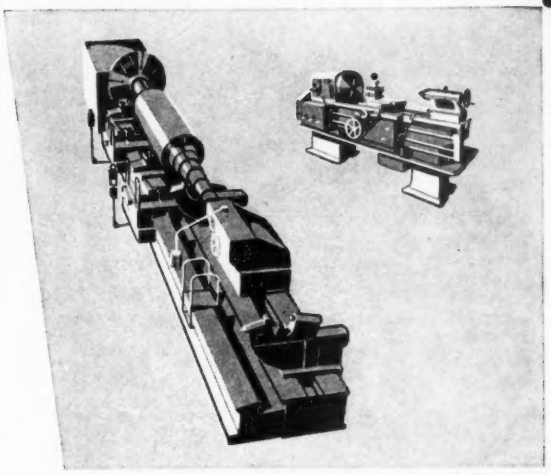

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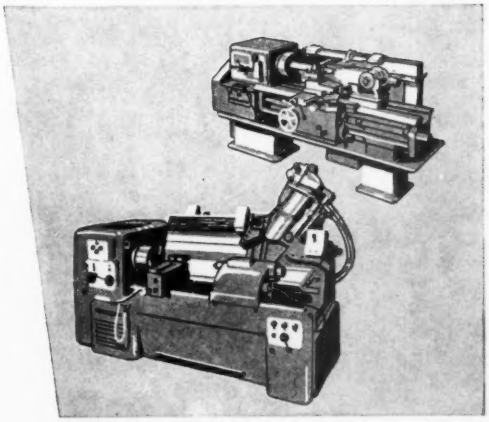

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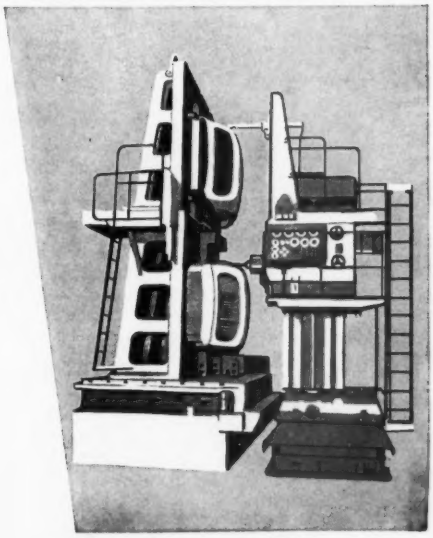

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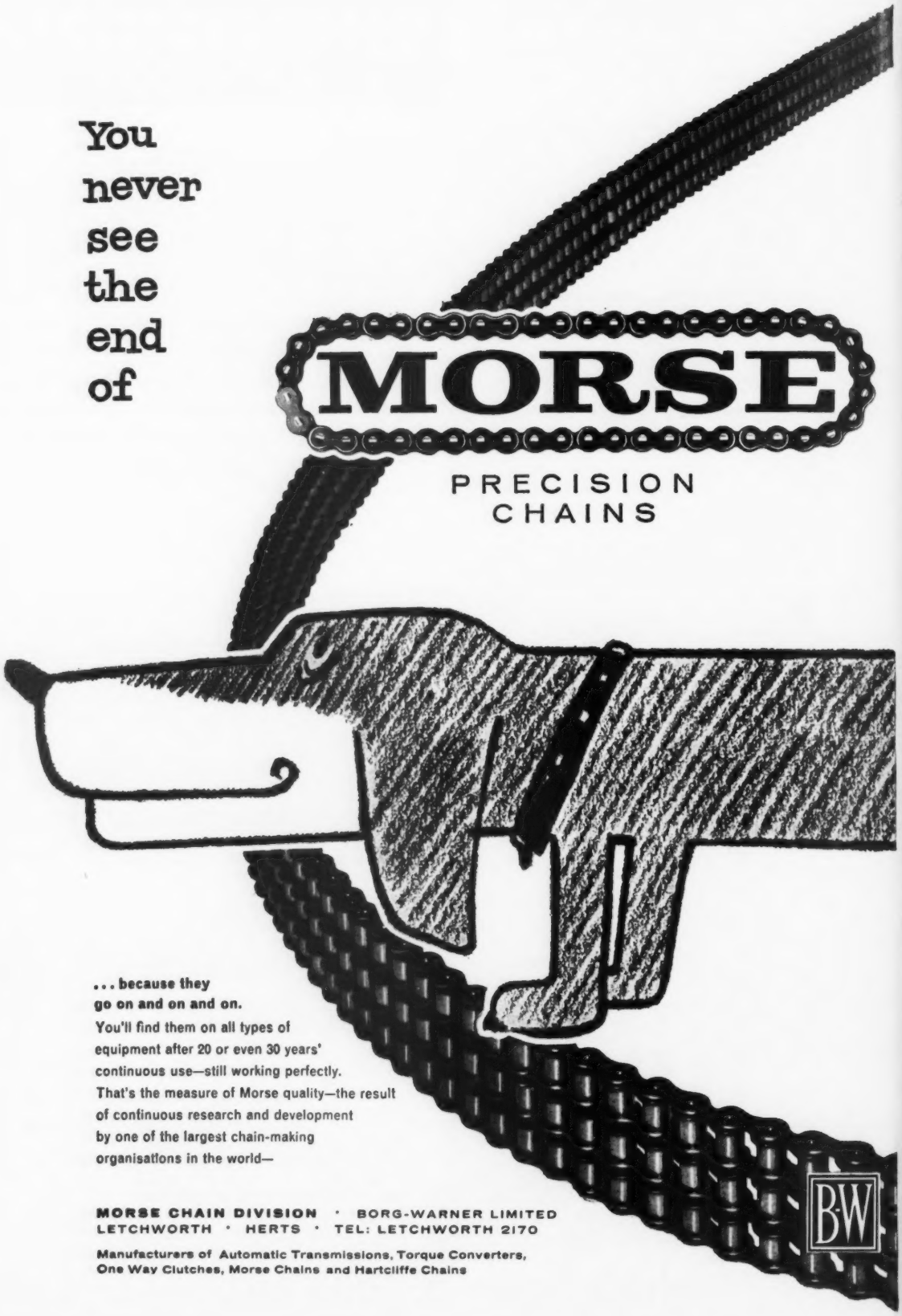

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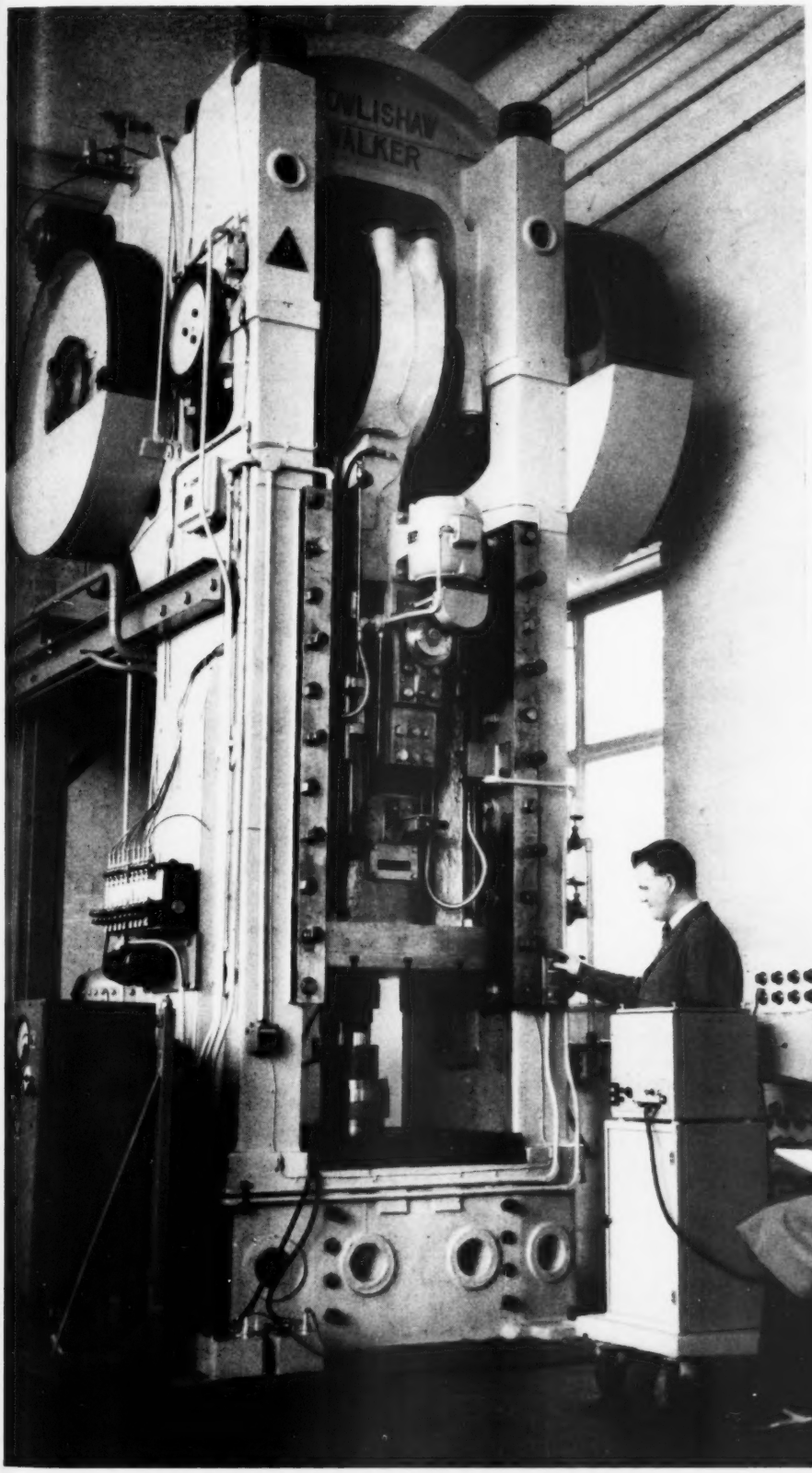

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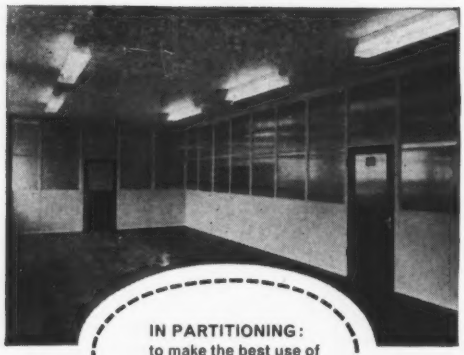

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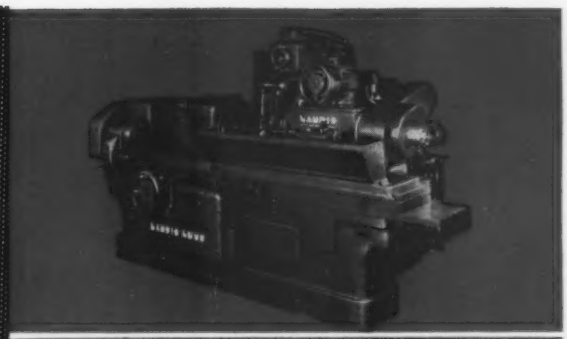

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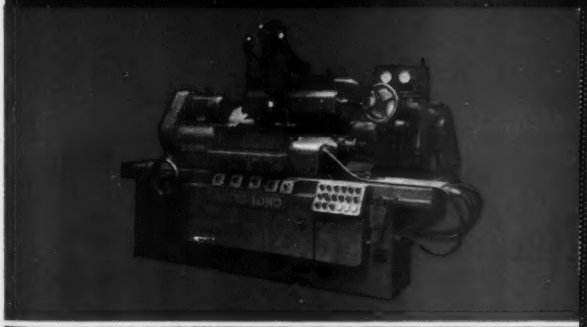

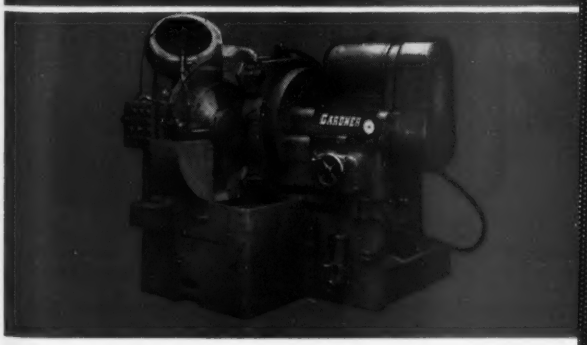

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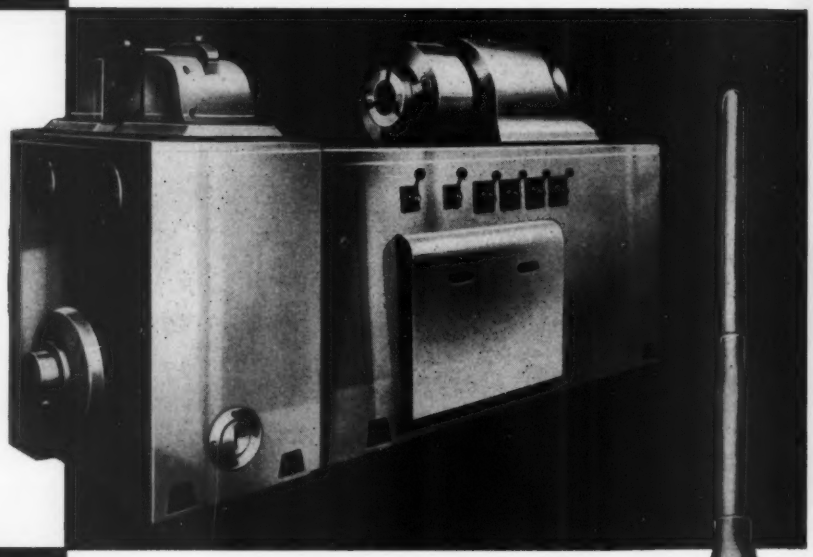

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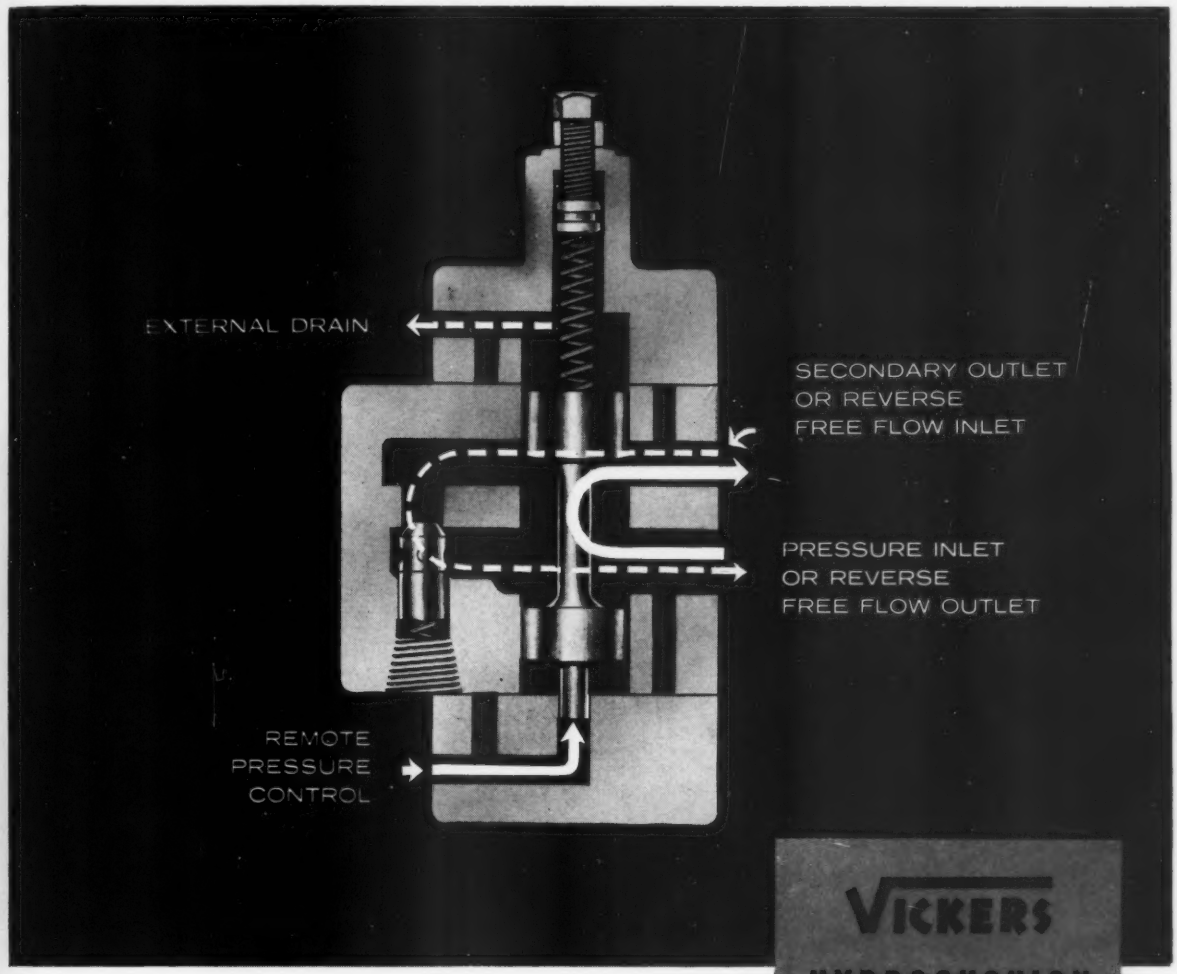

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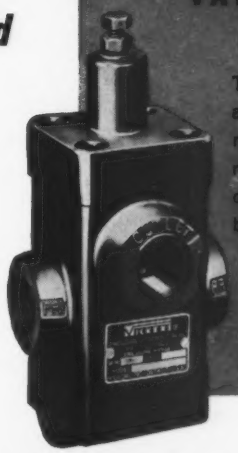

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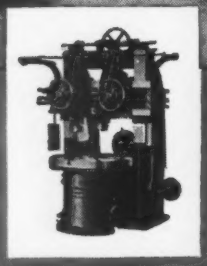

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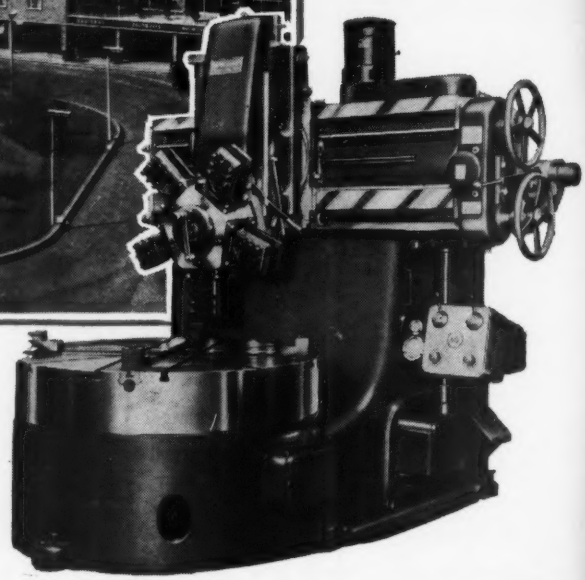

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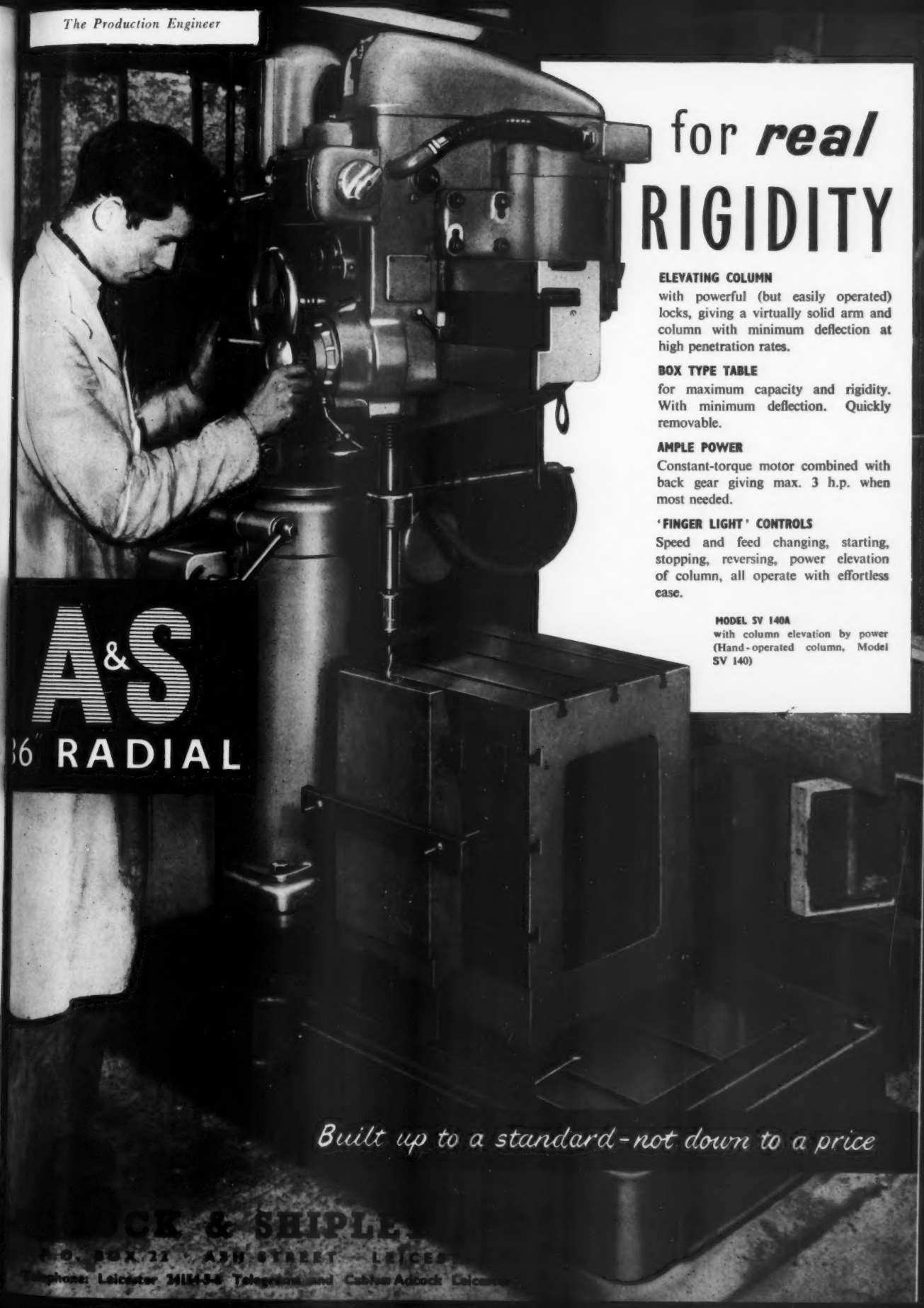
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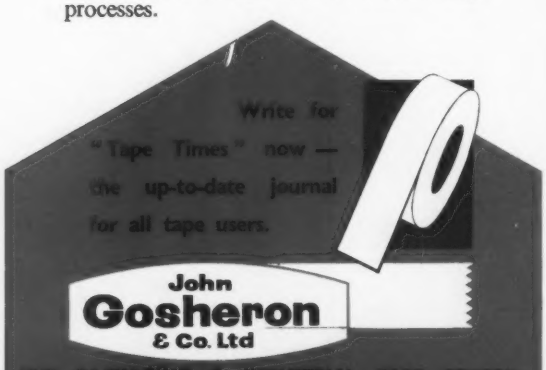

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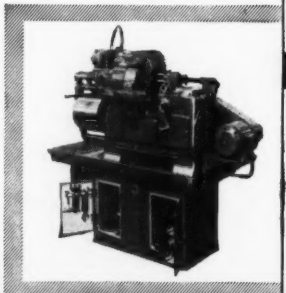


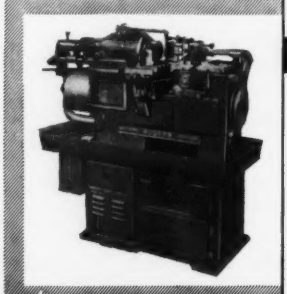
TYPE 904

CAPACITY

Round Bars. Dia.	⅞"
Hexagon Bars. A/F	0.71"
Square Bars. A/F	⅝"
Maximum Travel of Tailslide	2"
Maximum Travel of cross slide	1⅛"

SPINDLE SPEEDS

Speed Range	810-2,500 r.p.m.
No. of Speeds	14



TYPE 907

CAPACITY

Round Bars. Dia.	1¼"
Hexagon Bars. A/F	1.01"
Square Bars. A/F	1"
Maximum Travel of Tailslide	2½"
Maximum Travel of cross slide	1⅜"

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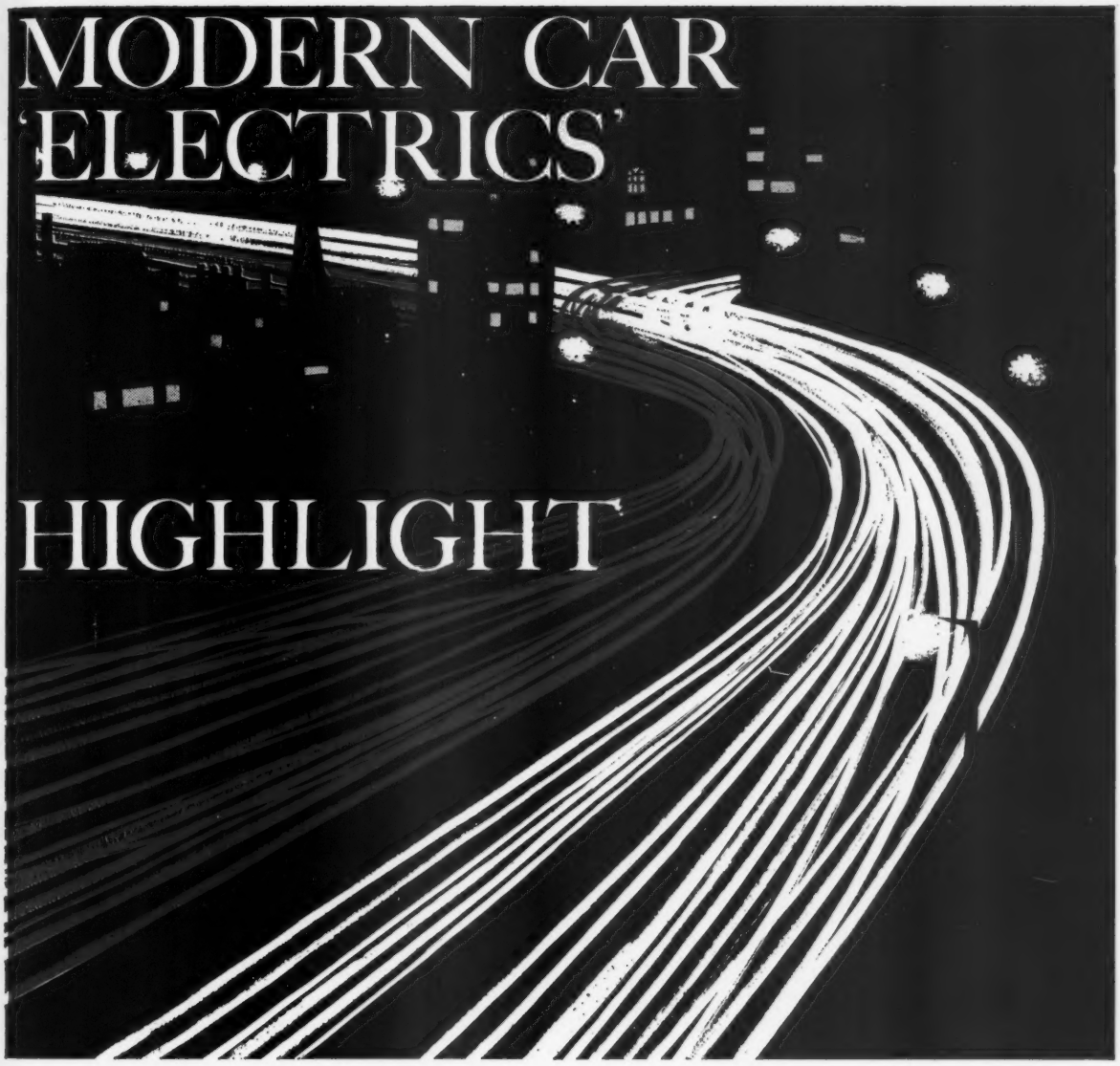
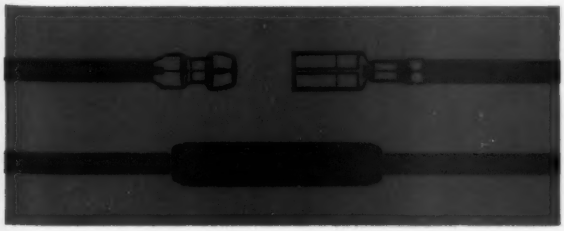


HIGHLIGHT

THE NEED FOR *A-MP



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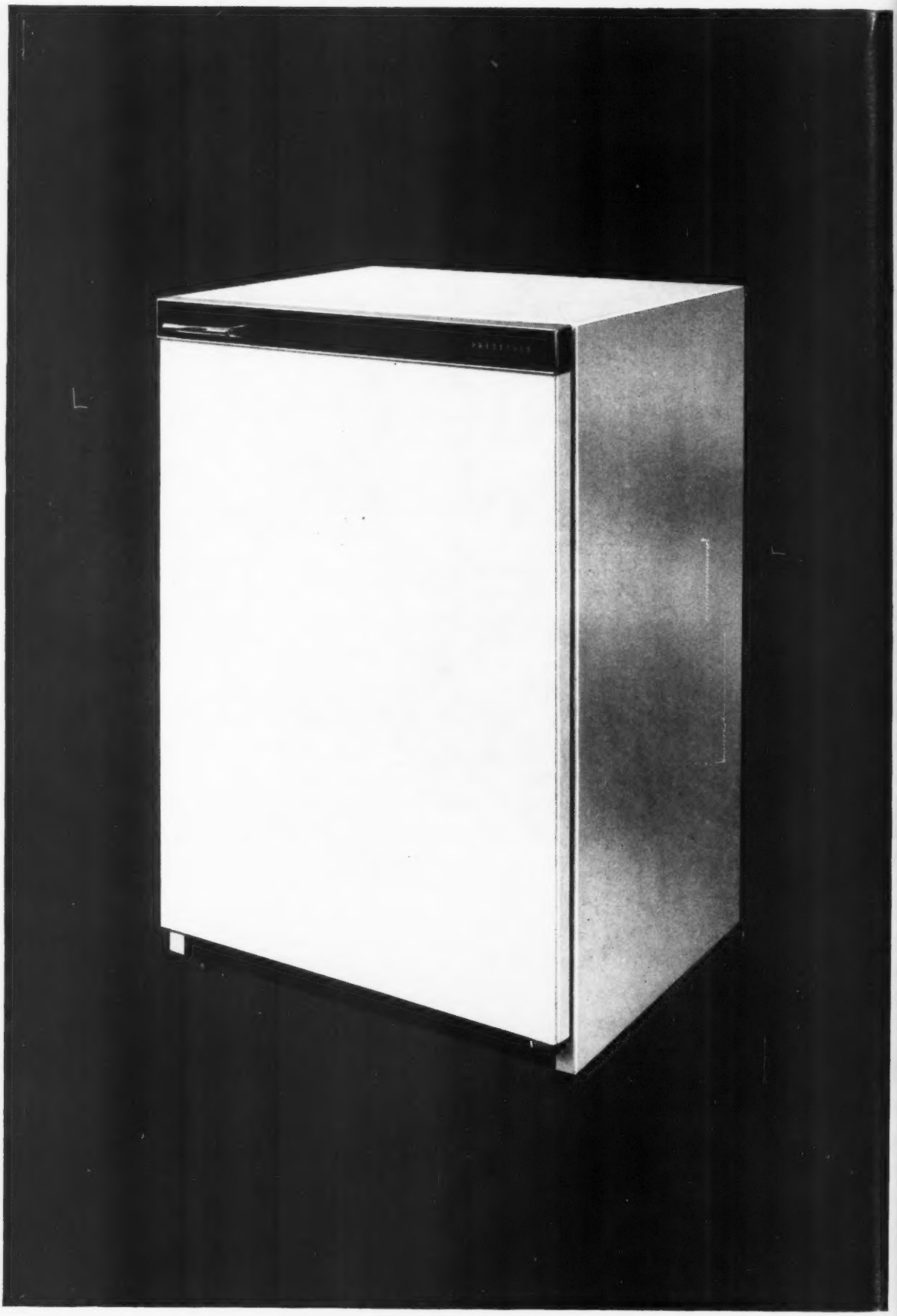

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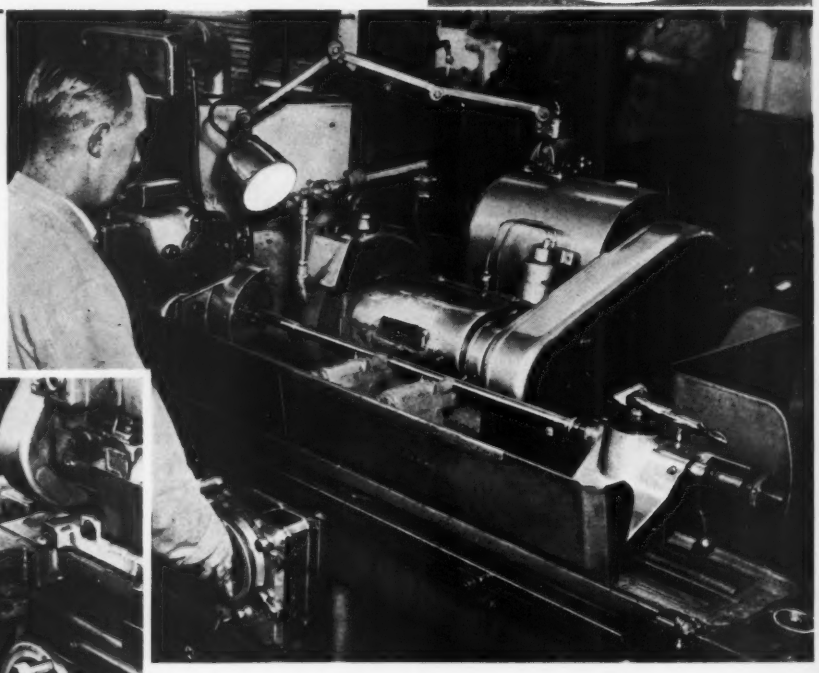

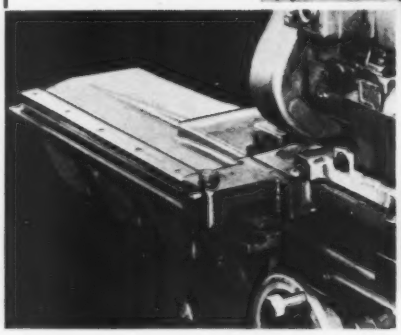

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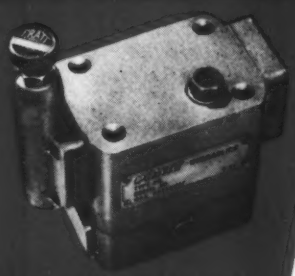
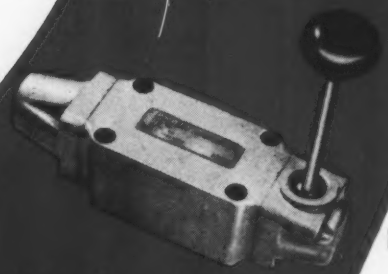


PRESSURE CONTROL VALVES



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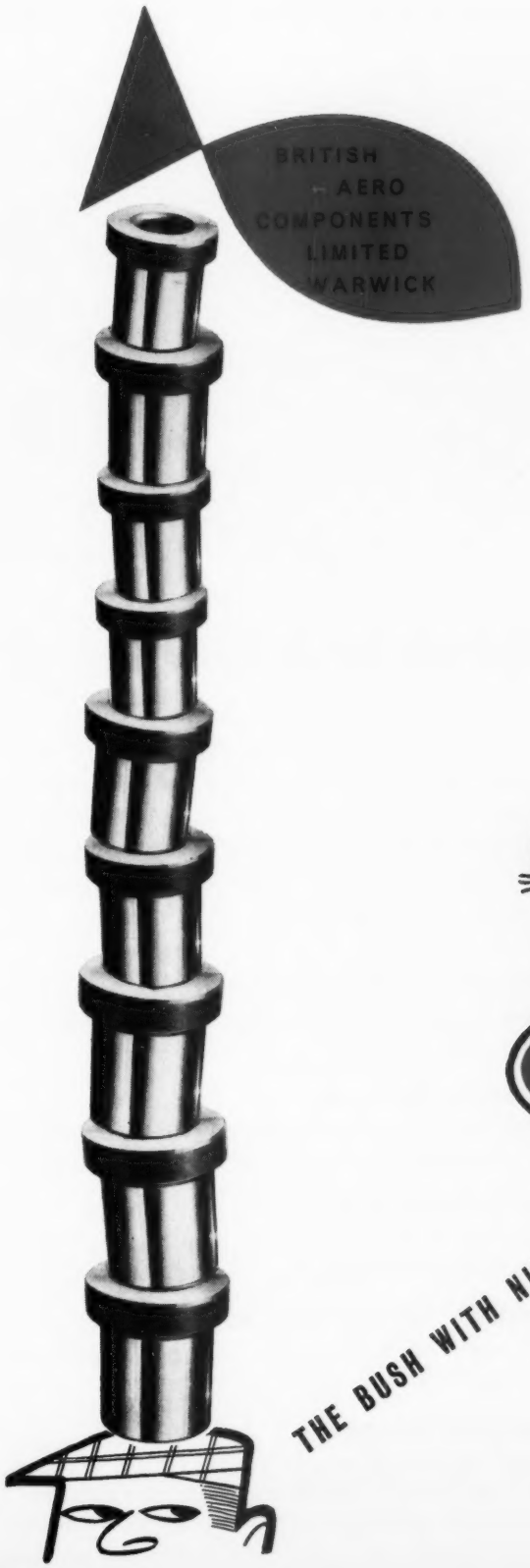

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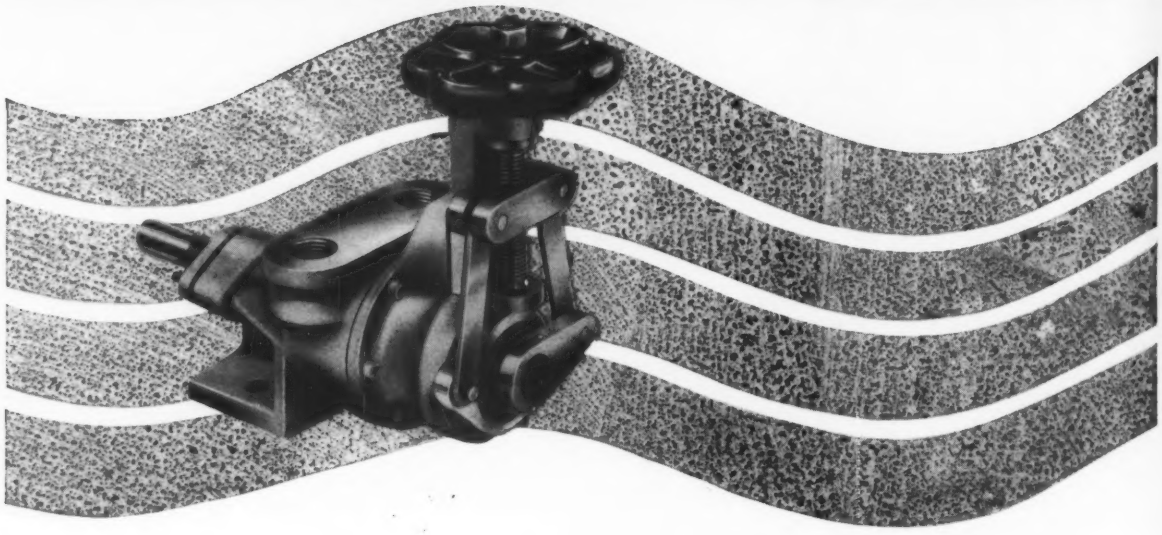

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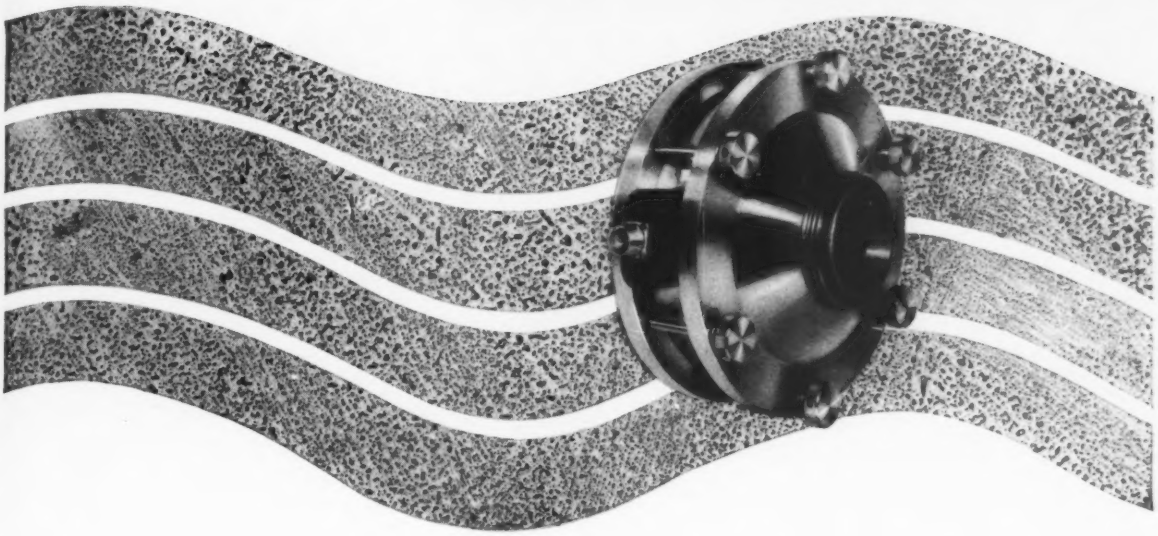

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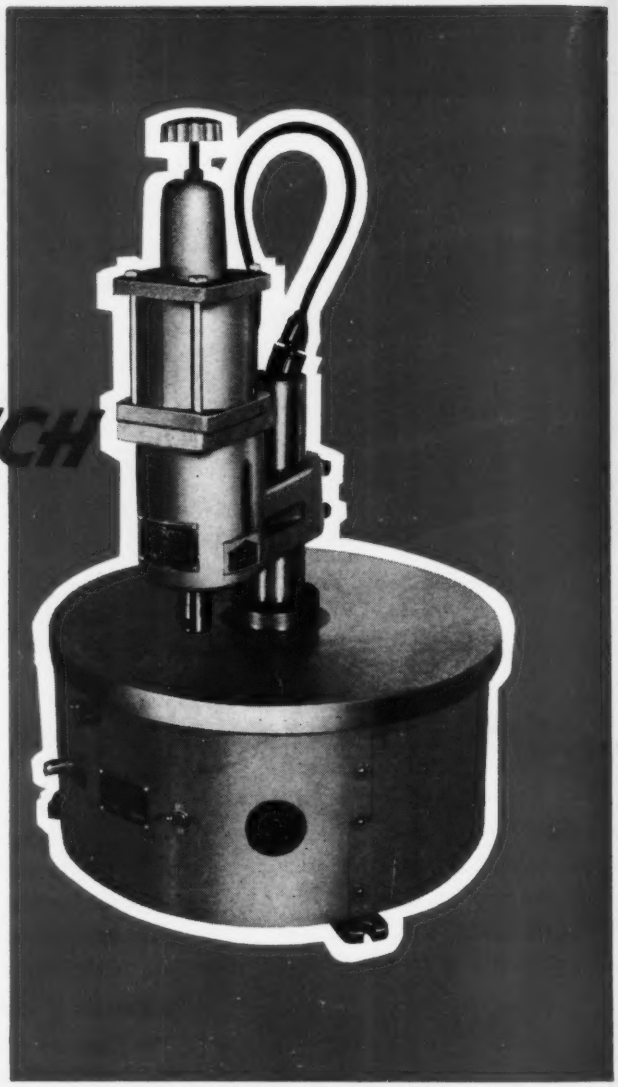

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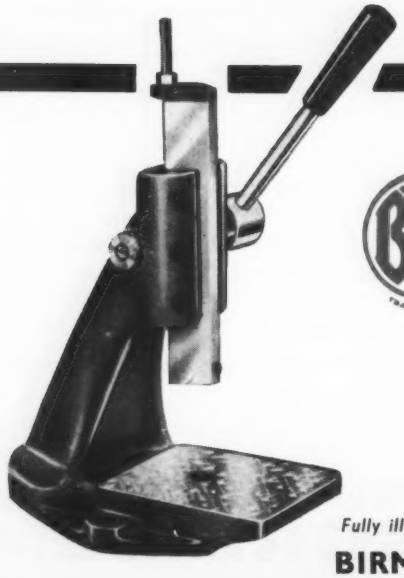

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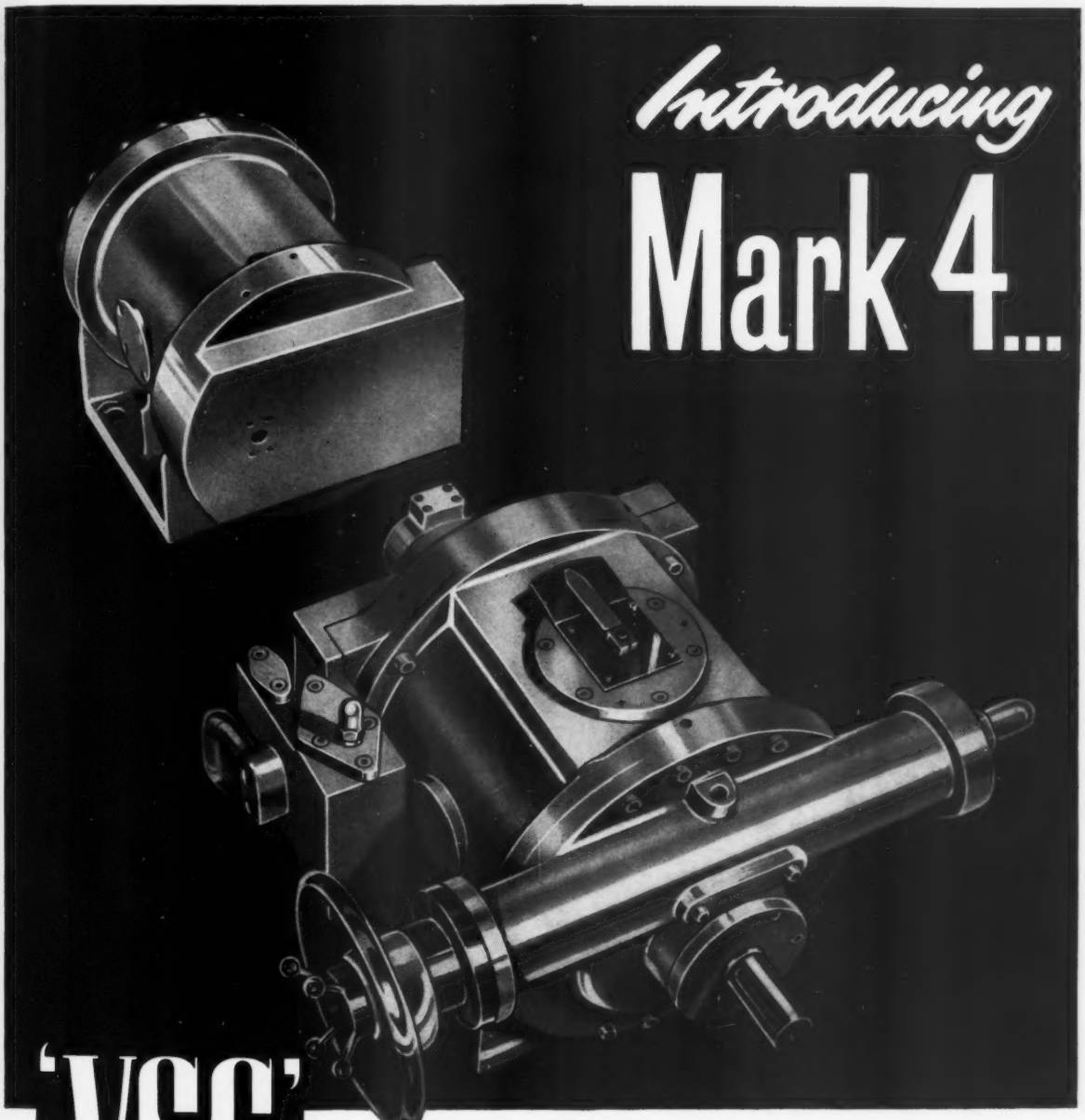

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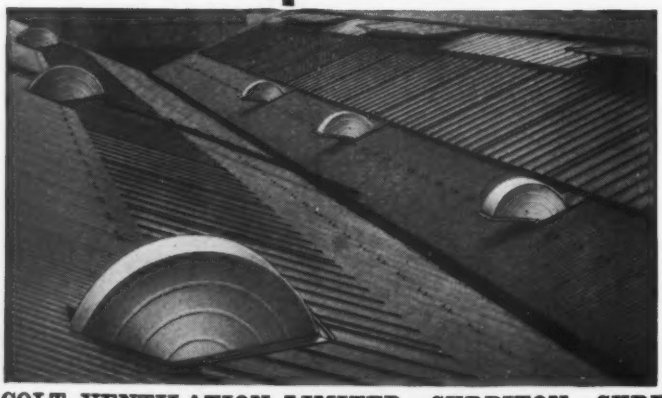

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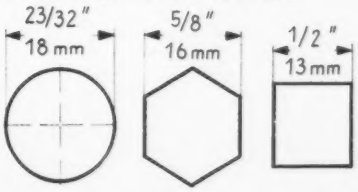

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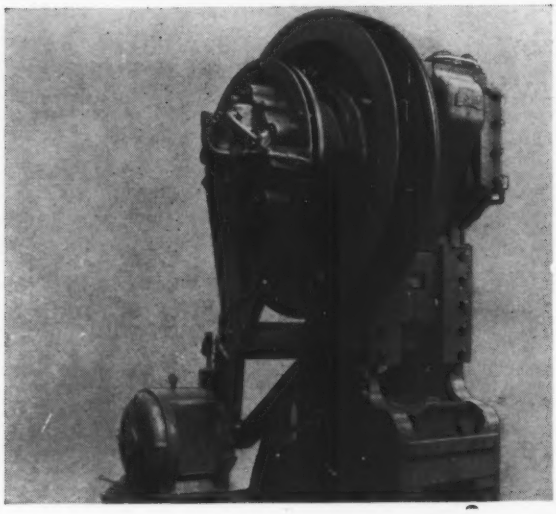

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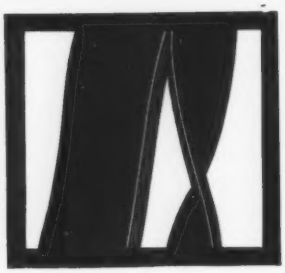

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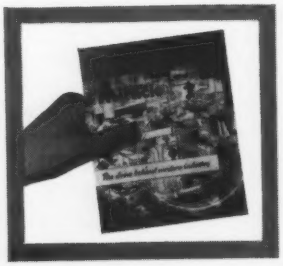

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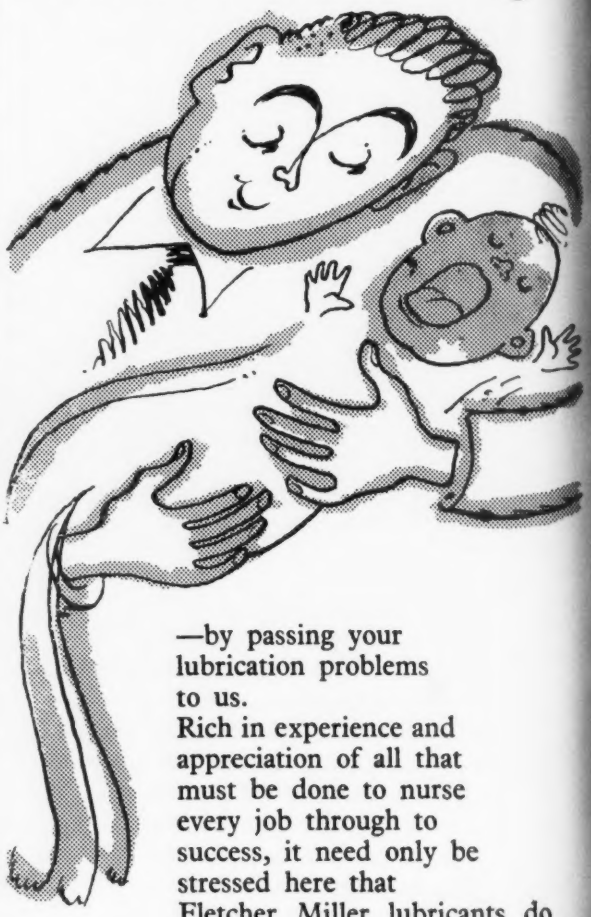

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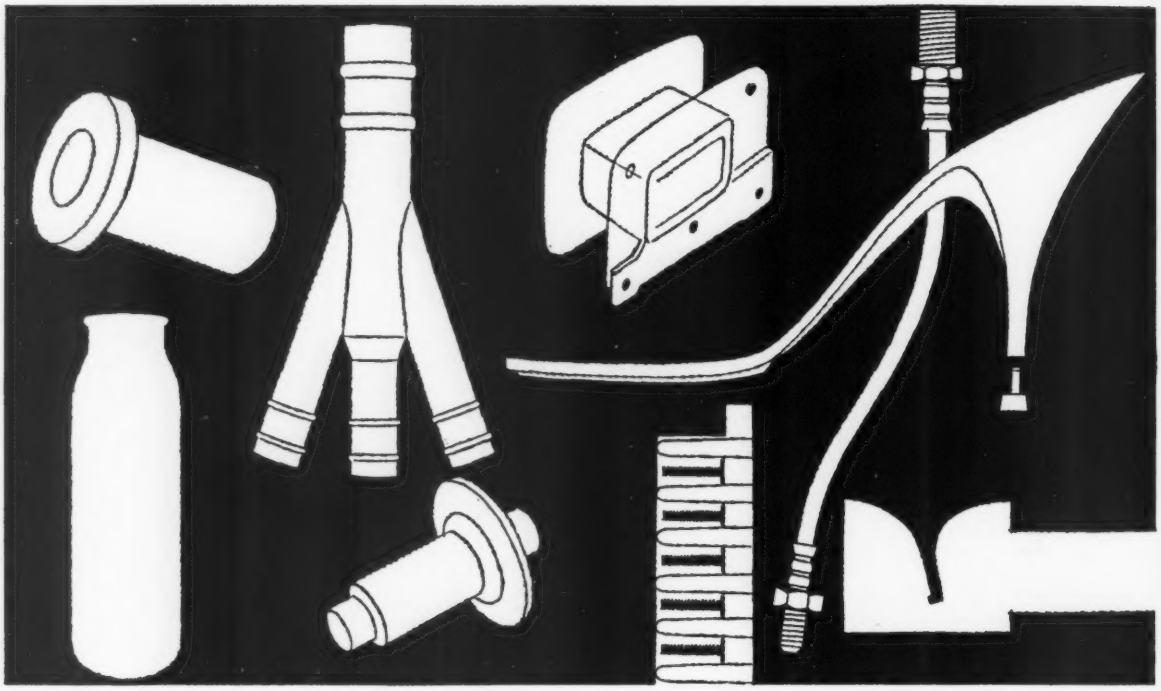

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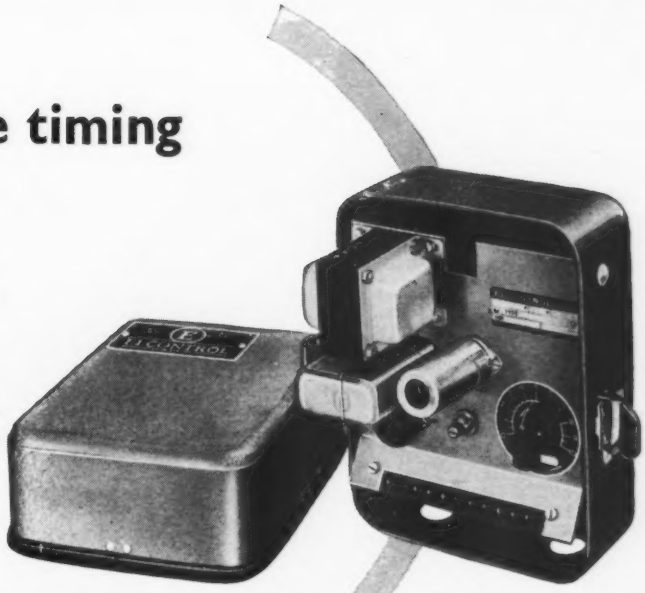

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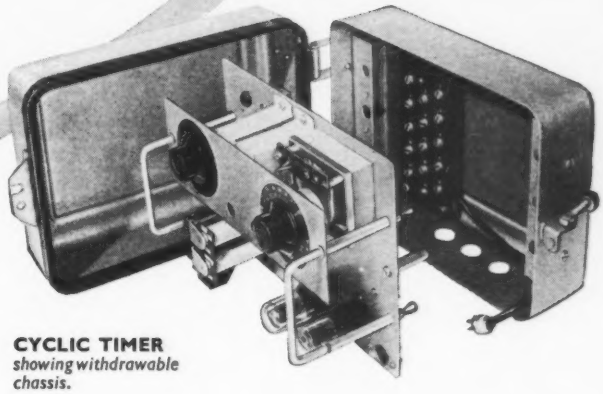

CYCLIC TIMER
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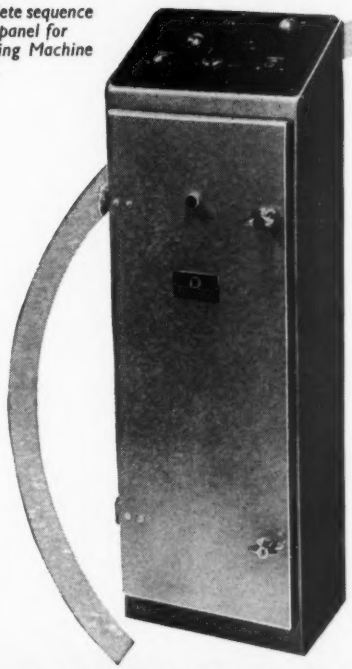

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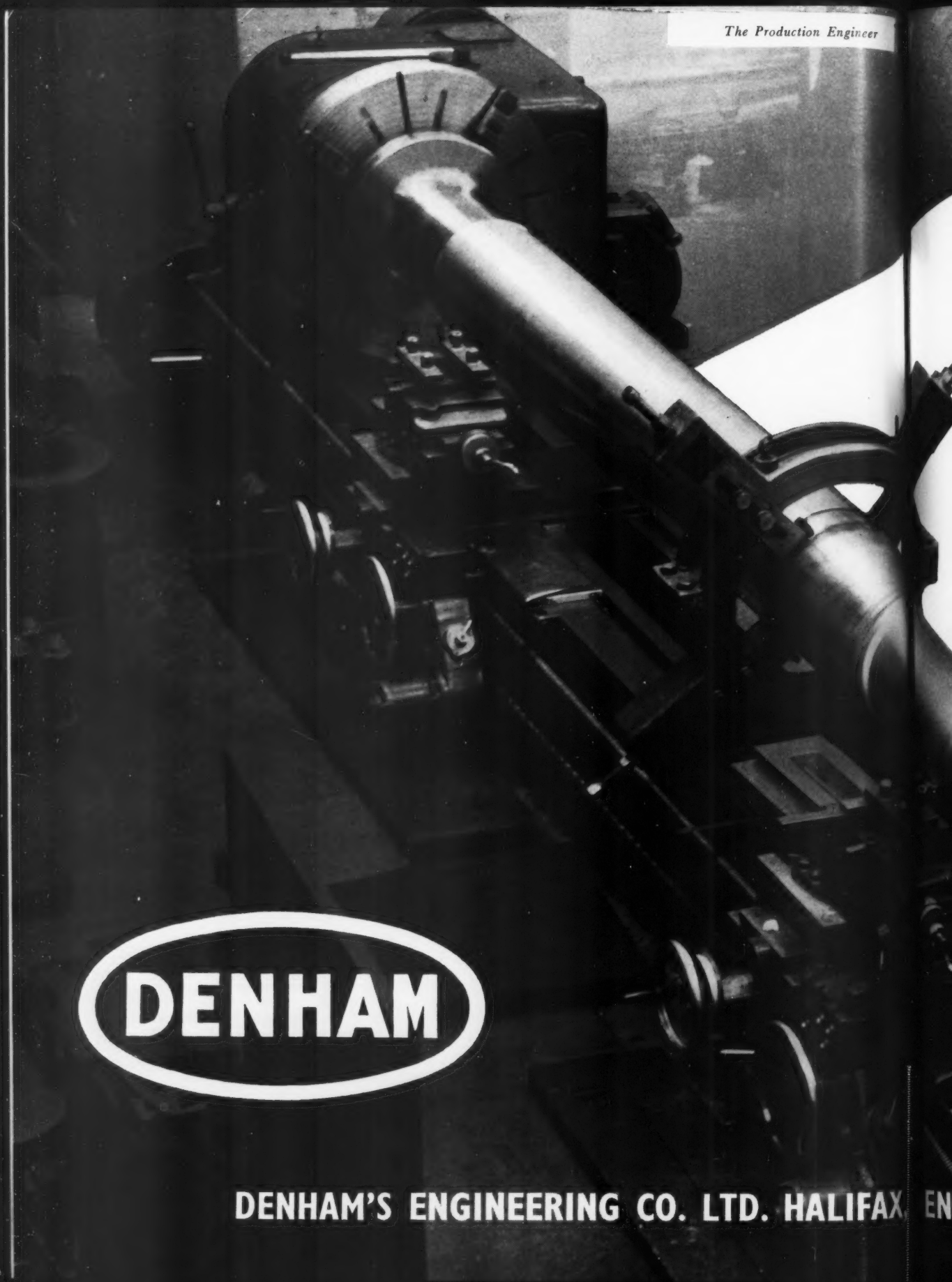

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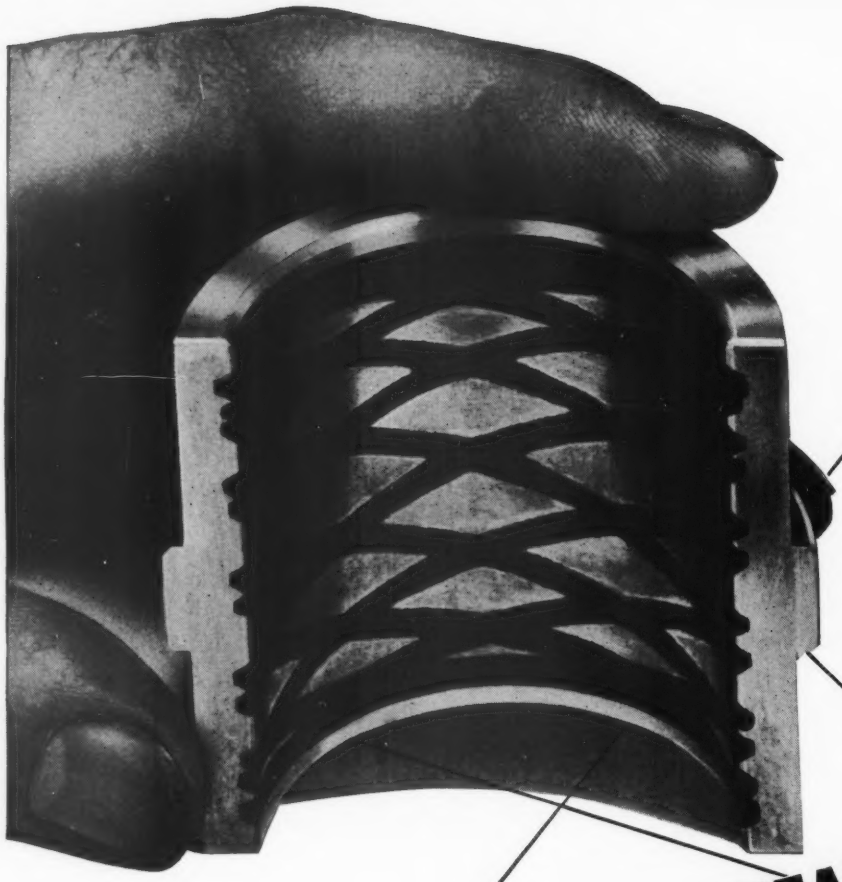

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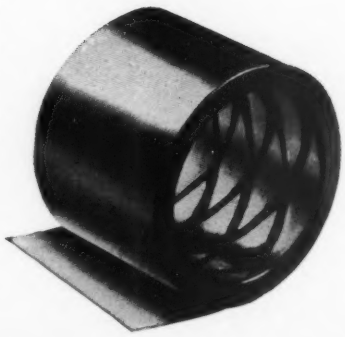

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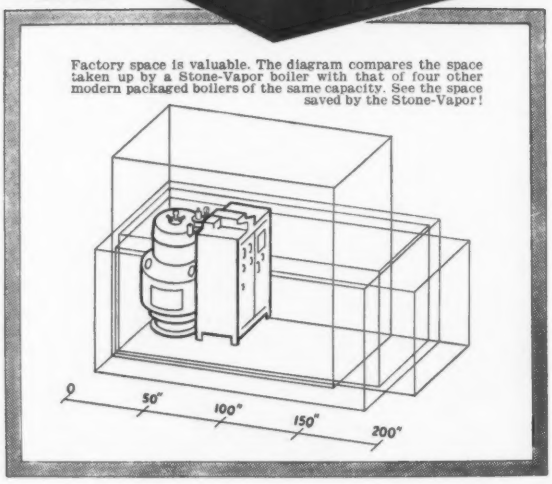

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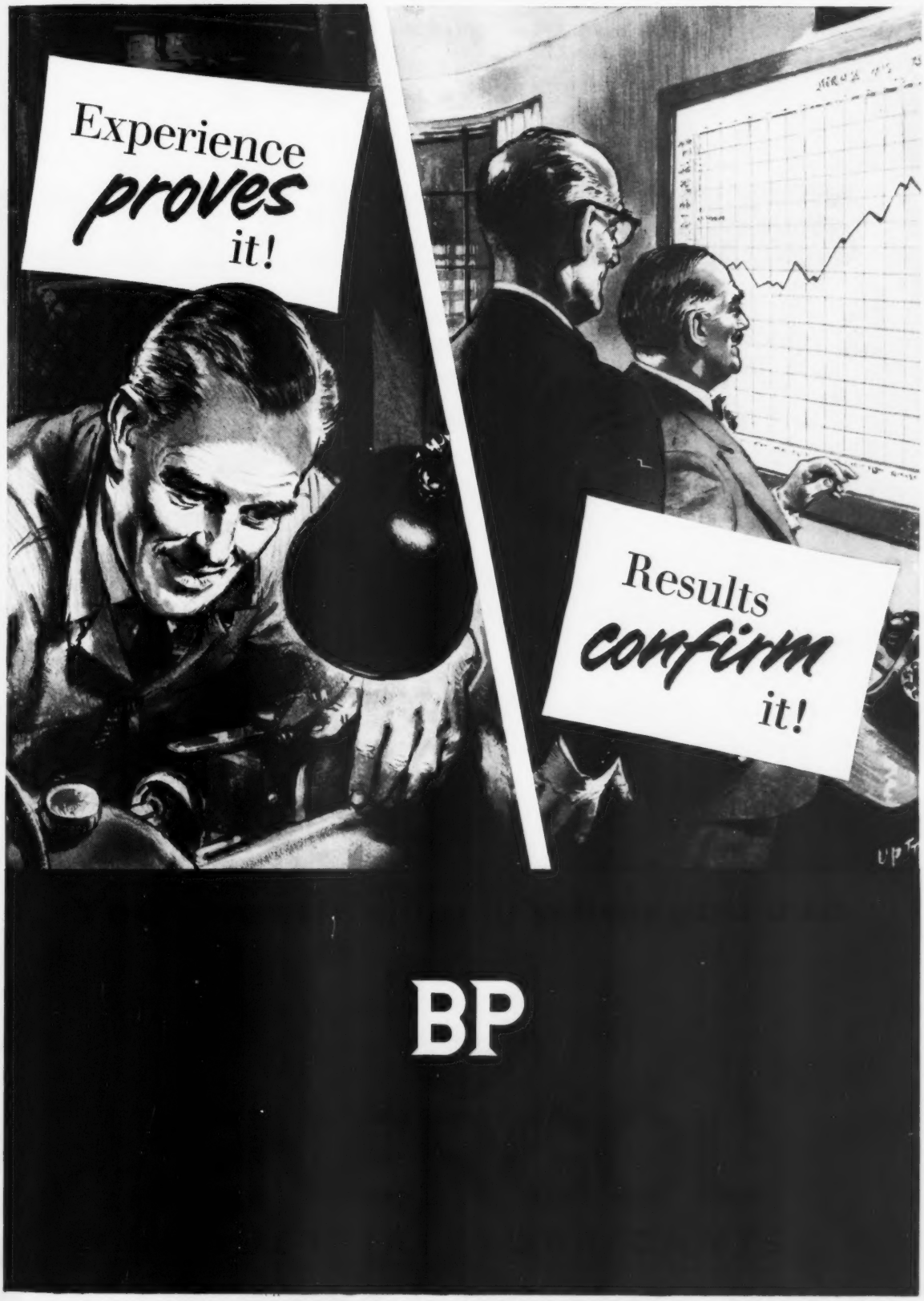

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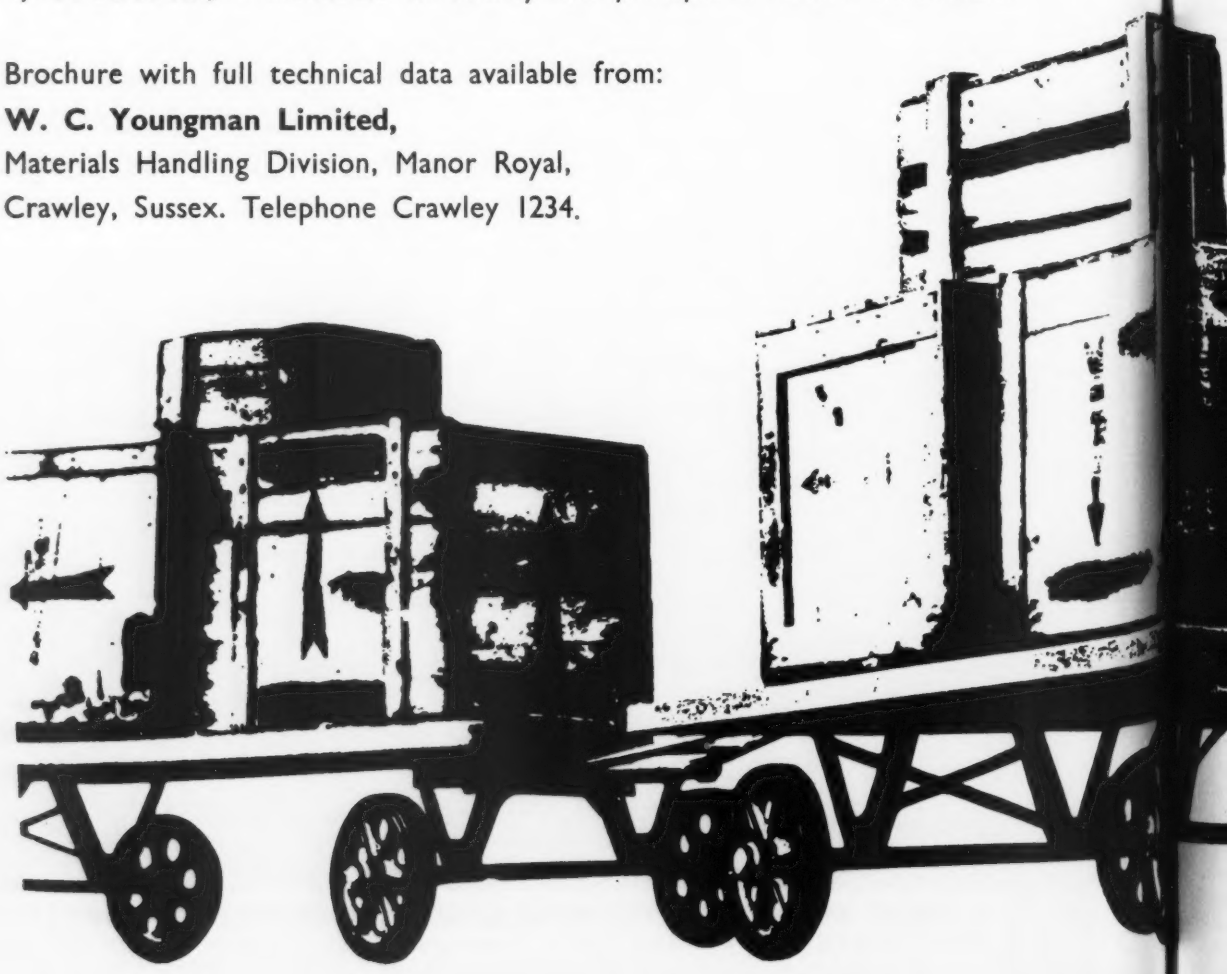

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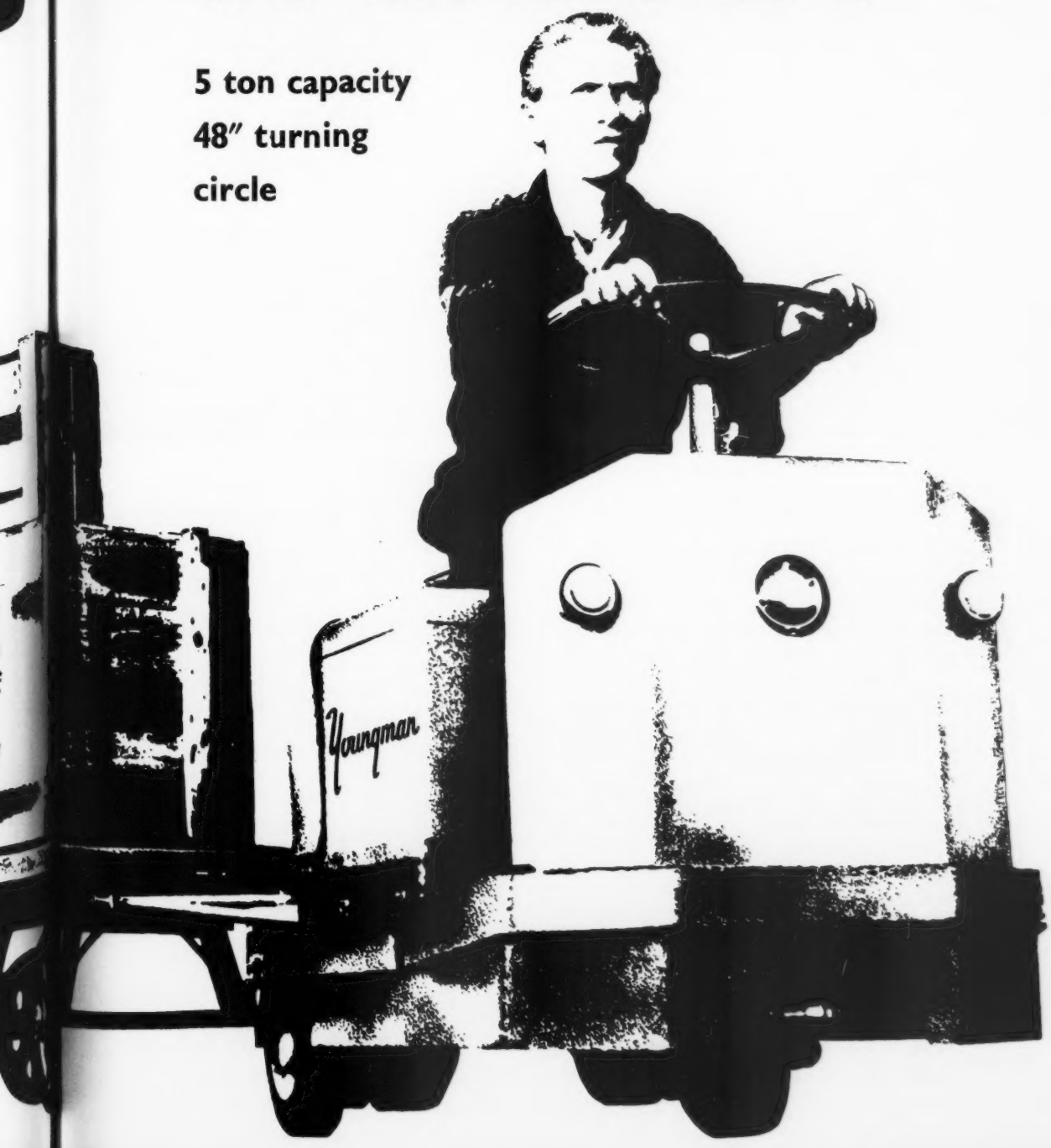

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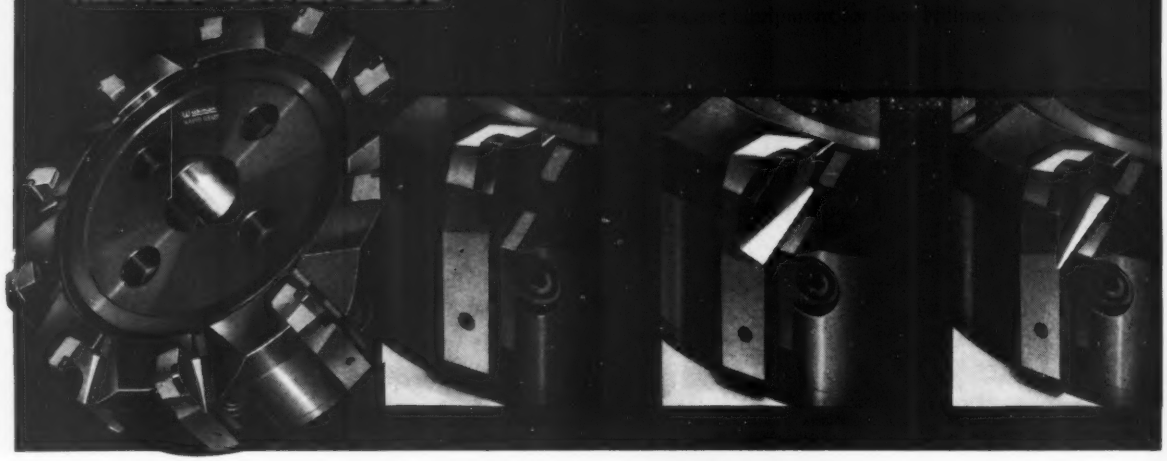

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The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 40 NO. 5 MAY, 1961

MANAGEMENT OF MANAGERS

by J. D. PEARSON, J.P., B.Sc. (Eng.), Wh.Sc., F.R.Ae.S., M.I.Mech.E., M.I.Prod.E.

Chief Executive and Deputy Chairman, Rolls-Royce, Limited

Mr. Pearson, who is of course well-known to many of the Institution's members, was the guest speaker at a luncheon meeting in London arranged by the Industrial Co-partnership Association on 9th February, 1961.

His address is reproduced here by kind permission of the Association.

AS what I say is bound to be coloured by my particular background and experience in industry, I think it desirable to give you first a brief personal history.

I was fortunate in being apprenticed in an area where the old-fashioned sandwich scheme operated, which enabled me both to complete a full apprenticeship and obtain an external London Engineering Degree at the same time. I lectured for a year and obtained a Senior Whitworth Scholarship which I took at Metropolitan-Vickers on steam turbine research. I then joined Rolls-Royce 28 years ago, and have been with them ever since.

During this period I was also fortunate in having worked on design, development, production engineering, sales and service, quality control and production management, before becoming a General Manager. For the last seven years I have been in charge of the Aero Engine Division, and for the last three years also Chief Executive of the Company. The Aero Engine Division, which employs 37,000 people, poses a particularly difficult management problem because of its size; unfortunately the nature of its business does not permit it to be broken down into smaller units. I shall thus be largely drawing on experience gained in the management of a large unit.

fluidity of structure

So first I would like to talk about the influence of fluidity of organisational structure on creative management. I am completely convinced, because of the inherently changing nature of the majority of the factors involved, of the need to maintain the maximum possible fluidity of organisational structure. The constantly changing nature of the external

factors, such as market requirements, Government legislation, scientific and technological inventions, needs no elaboration. Similarly, internal resources of individual management capability and availability of technological and managerial staff are also constantly changing. It is, therefore, to me self-evident that the ideal organisation which most adequately mobilises the internal resources to deal with the external situation can only be ideal at a given point in time.

Apart from the need to be constantly re-adjusting an organisation to suit the changing external conditions and the changing and developing talents of people, I believe change is inherently good for its own sake in stimulating creative activity. A good man takes up any new post full of ideas on how he is going to do the job better than the last man. When he has got his ideas accepted and working he tends to become a bit conservative and resistant to further change—that is the time to move him on to another job, if he is good enough, where he will be stimulated by the challenge of a new set of circumstances.

Furthermore, nothing is more stimulating to managers than the knowledge that the organisation is always sufficiently fluid to make the fullest use of their talents as they develop. Conversely, nothing is more deadening to a manager than the knowledge that his future promotion depends not on his ability and development, but on the availability of posts already held by others. This is of particular importance in an organisation with a young management, where the enthusiastic and capable young man arriving from university soon finds that his immediate superiors are equally capable young men, but with the added advantage of some five or ten years of experience. Unless he can be convinced that his promotion is not entirely dependent on his waiting for his immediate superior's job, he will soon be looking round for a post elsewhere. He can only be convinced by the facts, and one should be in a position to illustrate by example that the organisation is deliberately kept sufficiently fluid to enable young men of ability to make rapid progress up through the hierarchy.

Company philosophy

Company philosophy is also important to managers. Each Company has elements in its philosophy which are peculiar to its history and to the nature of its products, but there are in my view broader aspects of Company philosophy which could have a more general application. One of these is the political nature of the organisation, using the word "political" in its non-party sense. The days of an autocratic form of industrial government have largely passed. But I doubt if the truly democratic nature of large areas of modern industry is fully appreciated.

I believe that industry has a major contribution to make in developing a truly democratic society in this country and the one-nation concept. Whether we like it or not, we are an industrial society and the development of our social customs will be increasingly influenced by those of industry. Fortunately, I believe that these views are shared by a large number of industrial managers, who are more than receptive to all the steps taken to further this ideal.

Conversely, I believe that managers are resentful of any actions which hinder the spread of democracy in industry and, particularly, attempts to maintain some of the autocratic and aristocratic forms of the past.

unity among managers

Industry also has a unique opportunity to further the one-nation concept by fostering a genuine unity among its management, which will invariably have within its ranks individuals who started life in all the different levels of present-day society, who were educated at all types of schools, technical colleges and universities, and who come in with all the different variety of accents. Here is the melting pot where people with diverse upbringing and background can be fused into a genuine unity.

This is made easier where the so-called top management work and live in the same area as the major manufacturing unit, which brings me to my next point concerning the location of industry and management. I am firmly of the opinion that the best results can be obtained by having top management located in the same area as one of the major manufacturing units, which usually means away from London. The need for the headquarters to be in London will vary with the nature of the products, but I am convinced that unless this need is overriding the management of managers is much easier from a headquarters adjacent to a major manufacturing unit. The tension which is liable to build up between a London headquarters and manufacturing divisions is largely eliminated. It is less easy for the top management to lose the common touch.

importance of social life

Under these conditions, the top management of a large industrial unit have the opportunity to take a leading part in local social life. The objections often raised of making social contact outside working hours with the people with whom one works during the day are not really valid in a large organisation. It is usual to have many personal friends in the Company whom one never meets during working hours. If, in addition, positive steps are taken among industrial organisations in any particular district to encourage social activity between their managements, a very healthy and stimulating series of social contacts can be maintained. In this way the truly democratic society, which is already beginning to exist to quite an extent within large industrial organisations, can be spread into local society.

The leaders of such a local society based primarily on the top management of industry, the majority of whom have arrived at their position in a most truly democratic way, are capable of drawing in the other elements of religion, education and the arts, and contributing to local leadership in all aspects of local life. Furthermore, when such areas of industry are surrounded by countryside they are equally capable of co-operating with rural and county interests. Here, I believe, is a pattern capable of forming the basis of

the development of a lively culture, led by an essentially democratically selected creative minority but one which is still closely in touch with, and acceptable to, the majority.

Such a local society can provide a social framework into which the young manager and his wife can fit and feel genuinely at home. The more he can be encouraged to participate, the faster and deeper his roots will sink. This benefits the Company, and in my view it helps the individual as well.

Once the democratic idea is accepted, then actions and decisions begin to be made within its context. For instance, all privileges and status symbols come under its searching light and many are found to have little justification in a democratic group. It will often be found that there are far too many social grades of lunching, for instance.

Starting and finishing times should be the same for all levels of management, although one must accept that top management, being only human, must be allowed to cheat occasionally, as long as it is accepted that they are cheating and have no right to come to work late.

All forms of perquisites must be rigidly controlled and where they are used, used openly. The days when the workman was stopped taking a few pieces of wood out of the door to help light his fire, when loads of the same wood were delivered to the manager in a lorry, are, I hope, already on the way out, but more subtle ones still exist.

assessment of promotion

Promotion must be by merit alone, as it already is in most large organisations, but great care must be taken to ensure this and to let it be known that it is so. In order to reduce the possibility of errors and wrong judgments in this regard it is desirable that promotions should require the agreement of a number of people, not just one individual, of whom at least one should be outside the department concerned.

In a similar way, salary levels for those not covered by group agreements need careful consideration to ensure fair treatment for all. One system is to require a number of signatures on all salary change sheets. This circumvents any authoritarian tendencies on the part of managers and helps to ensure unformity of treatment between major departments, as one of the signatures required is always from a staff, as distinct from departmental, authority.

I would not wish the foregoing to leave you with the impression that I am in favour of a levelling down process, far from it. Modern industry has shown quite clearly that an *élite* is essential. All I want is for this *élite* to be a genuine *élite* of quality and creative ability, shorn of the false trappings of the past and democratically selected; in fact Toynbee's Creative Minority drawn from and acceptable to the majority and a genuine part of it.

One of the interesting phenomena of our times is the extent of the commitment of the majority of managers to their jobs, despite certain apparent disincentives such as the high rate of taxation on earned income. In my experience, one of the main problems with managers is to stop them overworking by putting in too long hours and not delegating enough detail work to others.

I would suggest that a comprehensive study of what provides such incentive for hard working on the part of managers might lead to some very interesting results, which might be applied down the scale. I believe that we are, maybe, wrong in looking at money payments as the overriding incentive. We, for instance, give individual contracts to a considerable number of our skilled operators, which give them certain benefits, but I believe that these contracts are sought after more for the prestige they confer than for the monetary benefits.

There is also a tendency nowadays to assume that large industrial organisations demand the total allegiance of their managers, almost to the exclusion of all else. I do not believe that a Company is best served in the long run by people who try to make the Company their whole life. My ideal is the manager who gets full satisfaction out of his work, but at the same time lives a full life outside. Company philosophy should always keep this in mind and never attempt to take over the whole man.

the dual approach

Managers can be helped in two directions: one, to get the best out of themselves in their own job; and, two, in getting the best out of the people they have to manage. It is most important that there should be no inconsistencies in these two approaches and this is much more difficult than might appear. It means that Company philosophy in dealing with people must be consistent right from the top to the bottom. It must start with the acceptance of the importance of people to the Company, and a policy of encouraging the development of each person up to the extent of his capacity, and then endeavouring to place him in the job which uses that capacity to the limit. This is an easy thing to say and by no means new, but top management should be constantly on the look-out to ensure that they are accepting all the implications and honestly trying to live up to these professions.

The problem of the specialist manager requires separate consideration. Unfortunately the vast field of technical development which has opened up, particularly in the last 20 years, makes it inevitable that the development and production of many modern products require the services of a considerable number of specialist managers.

To persuade a man to continue to specialise over a narrow field, and thereby cut himself off from many possible lines of future promotion, needs particular inducements. Care should be taken to maintain the status of specialists within the organisation. Outside, they should be encouraged to take as full a part as possible in the activities of the various associations of their speciality. They should also be encouraged and given the maximum freedom to publish Papers in their field and to attend international conferences. In other words, they should be given every opportunity to build up their external status among fellow specialists.

Such encouragement is, of course, desirable in all technical fields, but the balance has always got to be struck between the compelling needs of the job and the need for spending time on external contacts. All I am suggesting is that the specialist should be given special consideration in this regard.

training for management

There is little new to be said about the need of training for management. I would, however, draw your attention to two aspects of training for management which are often confused — the first is the acquiring of known techniques. These can be acquired by reading, by part-time study at most technical colleges, or by courses as part of a university training. Many individuals who receive their university training in a technology get little or no training in management before they join industry. If a man who has elected to make a career in technology feels that he wants to prepare himself for management, then in my view he should take the initiative in doing so. I am not generally in favour of residential courses for passing on management techniques to those who have already reached degree standard in other subjects.

The second is the development of managerial or executive ability. In the past this has largely depended on training by contact with existing executives. This is still by far the most important means of developing future executives, provided existing executives are of the right calibre. In addition, however, I am a firm believer in the desirability of outside courses aimed specifically at executive development.

The Company method of training executives inevitably trains them only in the field of the Company's activities, and usually trains them only in the field of activity of their immediate superior. The benefit of the external executive development courses are many. They provide a manager with an opportunity to get away from his job and an opportunity to revive his process of thinking and reasoning on new problems. They introduce him to many aspects of industrial life of which he has been only vaguely aware. They bring him into contact with like people in other industries. They help to correct the great danger of inbreeding, which is ever present in a large organisation. Somewhat similar benefits are obtained by those managers who are given the opportunity to travel abroad and visit other factories. A very conscious effort needs to be made to ensure that managers are given an opportunity to visit other companies.

If we could only bring our standards of management in all departments up to the best standards already attained in this country, we would achieve a staggering improvement without any new ideas or inventions. This is another reason for encouraging inter-company visiting and inter-divisional visiting in large organisations.

communication problems

The problems of communicating with managers is clearly of great importance, as the enthusiasm and energy with which they tackle their job must be influenced by their acceptance of and knowledge about how it fits into the Company activity as a whole. This is easy to impart in principle, but in addition it is desirable that they understand the reasons for the day-to-day decisions of management which affect their own departments.

A system that we have found to work fairly well in the Aero Engine Division is the large weekly meeting to discuss and make decisions on matters which affect more than one of the main departments. The majority of the people at such a meeting, which may number 40 or 50, are there firstly to listen, although they know they are free to speak on any subject under discussion on which they either have specialist knowledge or strong views. Such a meeting is also a reporting meeting, at which both top management and the main departmental managers report on what has happened in the past week.

None of these schemes is perfect, but I do feel that this particular technique at least ensures that the majority of the senior managers do know what is going on and have listened to the discussions preceding decisions.

These meetings are held on a Monday morning, and the managers at these meetings are expected to hold their own meetings in the afternoon to pass on further down the line the decisions and information they have received from the morning meeting, as appropriate.

use of local amenities

Under today's conditions some of the responsibility previously felt by enlightened landowners for the encouragement of local amenities now falls on industry. Most large Companies accept this responsibility because apart from humanitarian motives, the state of the local amenities can have a direct bearing on their ability to attract and retain the type of personnel they need, many of whom of necessity must be recruited from outside the area.

I am not referring to Company-provided amenities in the form of sports grounds for the exclusive use of Company employees, but rather the encouragement of the general amenities of the locality. I would prefer, wherever possible, to support the improvement of local amenities and facilities for the general use of the local population, rather than develop them exclusively for Company use, thus again tending away from the paternalism of the Company-provided facilities. Companies should, and in many cases do, support a wide range of local activities, including the theatre, music and the arts, as well as sporting activities. The association of the Company with such local activities should be used as an opportunity to encourage the younger managers to represent the Company in these community efforts, thus helping to develop the whole man.

Managers should also be given every encouragement to take part in local activities, not excluding politics, and if necessary should be given time off to do so.

On the humanitarian side much progress has been made and today one of the dangers is paternalism, which tends to detract from the dignity of the individual. One of the ways of avoiding this is to

convert all forms of charitable generosity by the Company into schemes which provide such help as a right, usually in return for years of good service to the Company. This has, of course, already been largely done with pensions, but there are other things such as various forms of help in sickness and adversity, and conditions for early retirement, which should be dealt with in the same way.

A man's dignity as an individual can be increased by giving him an individual contract, by reviewing his salary on his birthday, not at some arbitrary date, by increasing the notice that he is to have if his services are no longer required, by ensuring he is aware that he has rights of appeal against any decision which affects his personal position, right up, if necessary to the Chief Executive of the Company.

It is unreasonable to expect any man to stand all day at his job if he can do it equally well sitting down. It is undignified for people we now like to call junior managers, i.e., foremen, not to have some form of office better than a dilapidated wooden shack. It is undignified for a man not to be able to remove the dirt he has accumulated on his hands and clothes in the course of his work before he leaves a factory, which does not necessarily mean that he is entitled to do this in his employer's time. I would personally be in favour of experimenting with the abolition of clocking on and off work, as in my experience if people are trusted openly they very rarely betray that trust.

As an example of this, when we introduced contracts for hourly paid workers we agreed to pay them a certain sum per day when they were off sick for anything over half-a-day. As medical certificates can only normally be obtained for absences of more than two days, the question arose as to what check we could make. We decided that we would make no check at all; all we would want from a man was a statement saying he had been unable to come to work because he was sick. We made a check on previous absence due to sickness and calculated what this was likely to cost in a year. In practice the actual cost to the Company of this sickness payment was only one-third of what we had estimated, based on previous records of absence due to sickness among the particular class of skilled men concerned. This speaks for itself, and is an illustration of the soundness of my belief in the essential decency and honesty of the vast majority of the people who work for companies such as Rolls-Royce.

In conclusion, I don't believe I have said anything fundamentally new about dealing with people, because I don't believe there is anything fundamentally new to say — it was all said a long time ago in the Sermon on the Mount. All I hope to have done is to have stimulated your thoughts, often by overstating my case on the application of these basic truths to the management of managers in today's circumstances in industry.

CONFERENCE ON

MACHINE TOOL DESIGN AND RESEARCH

The Second International Machine Tool Design and Research Conference is to be held at the Manchester College of Science and Technology from 25th to 29th September, 1961. This is to follow the successful Conference held at the University of Birmingham last year.

The Conference programme will contain Papers dealing with :

1. recent researches in manufacturing methods, such as machining (cutting, electric machining, ultrasonic machining, etc.), or forming;
2. results of recent investigations into the behaviour and performance of machine tools employed for the execution of processes mentioned above;
3. recent developments in the design and manufacture of machine tools and machine tool control systems;
4. productivity and economics of machine tool applications.

Contributions have been promised by leading scientists from universities and engineers from the industry in this country and the Continent.

Applications for enrolment forms should be sent to : *The Organising Secretary, Mr. J. P. Mahon, Manchester College of Science and Technology, Manchester, 1.* Early application is advised.

PRESSURE ECONOMY

by MELVIN D. VERSON

President,
Verson Allsteel Press Co.
Chicago, U.S.A.

Literally brought up in the press business, Mr. Verson has been directly associated with the Verson Allsteel Press Company since his graduation from the "Citadel" (Military University of South Carolina) in 1949.

He has spent time in virtually every department of the Company. Prior to his appointment as President, early in 1960, he had been Vice-President of the Company for four years, and has served in various other capacities including those of Executive Assistant and Assistant Sales Manager.

Mr. Verson is active in many of the trade organisations connected with the American machine tool industry.

IT is my pleasure to be with you today to talk on the subject of impact machining. If the terminology "impact machining" seems strange, it means simply this: cold extrusion basically carried to the point of eliminating finished machining. This is not always possible but represents an effort on our part to applying the principles of cold extrusion to the point where there is little or no machining necessary after extrusion.

The economies of this effort are quite obvious since the achievement of these aims results in a substantial reduction of raw material to accomplish the same piece part configuration, as well as the reduction of machining operations required by other methods.

Cold extrusion is a displacement of ferrous or non-ferrous material in a plastic manner. By plastic flow we mean something as simple as taking a piece of clay and squeezing it between our fingers, and displacing it at random to no geometrical proportion. This is plastic flow. In ferrous and non-ferrous materials the material can be displaced plastically to form a part of exact geometrical specifications. The part is confined in a die and displaced by a punch or punches to a final piece part such as a cylinder. That is cold extrusion. The material is put in cold, worked cold and produces the desired final piece part.

Throughout the years, extrusion principles have been applied to various materials such as aluminium, brasses, copper and in recent years to many other materials. However, this does not seem to carry the

strangeness that cold extrusion of steel implies to the uninitiated. To begin with, the fact that we extrude steel by using steel tooling appears on the face of it to be just a little strange. We start out using materials in low carbon steels that have a yield point around 37,000 lb. to 40,000 lb. p.s.i. and work it with applicable tooling. Basically, the first reason that we can accomplish this is that we have an efficient lubricant.

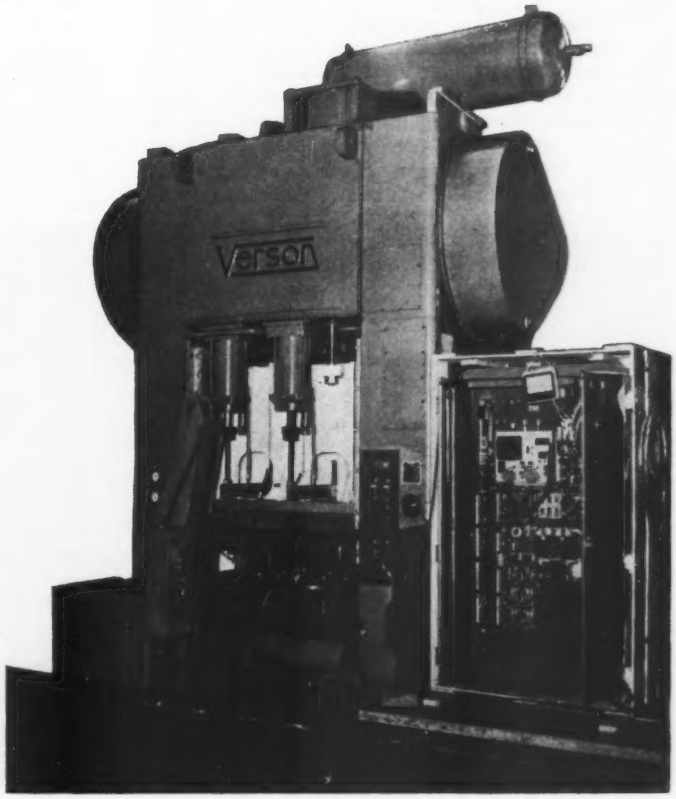
importance of lubrication

Without lubrication there can be no cold extrusion of any practical value. Lubrication prevents the tooling from galling and seizing and being destroyed by the surface friction that would be generated between the work piece and the tooling itself. The lubrication acts as a barrier and provides a low frictional value during the displacement of material by the extrusion tooling. To do this the lubrication must be able to stand unit pressures of 180,000 lb. p.s.i. up to and including 400,000 lb. p.s.i. The usual lubricants such as viscous, mineral oils, waxes, that depend on surface tension strength to lubricate are not sufficient for this type of work, and will not withstand the terrific pressures to accomplish economically successful cold extrusion.

The lubrication system that we use in cold extrusion consists basically of a zinc phosphate crystalline deposit that is bonded chemically with the base material by an intermetallic bond created during the deposition of the zinc phosphate. The crystalline deposit is subsequently impregnated and coated with a zinc stearate soap. At present there does not appear to be another system that will produce comparable results.

This system of lubrication is somewhat similar to that used in a pre-paint treatment. A pre-paint treatment phosphate would range in weight from 90 to 120 milligrams per square foot. However, a zinc phosphate for cold extrusion would range from a minimum of 800 milligrams per square foot to 3,200 milligrams per square foot for severe applications. So it can be readily seen that the zinc phosphate for cold extrusion is a very special one. It must react very efficiently with base material to exist in the environment of the high pressures required for the cold extrusion.

Once we have a good lubrication system there are other factors that must also be reckoned with. Referring back to unit pressures mentioned earlier on ranging from 180,000 lb. to 400,000 lb. p.s.i., we can see that the tooling application is a critical one. The tools must have the strength to withstand these high



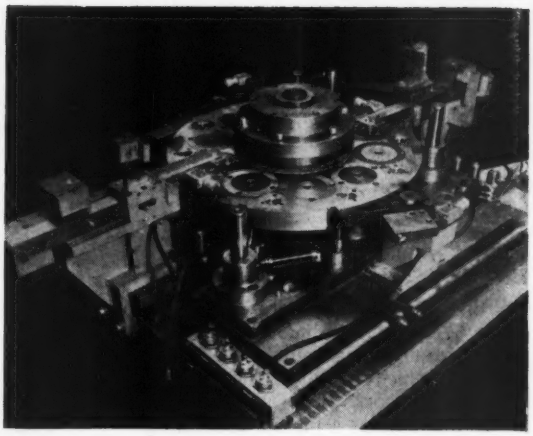
A 400 ton double crank twin drive production cold extrusion press, with dial type tooling and automatic feed.

unit pressures. The application of the tooling must be guided quite closely both for dimensional reasons and also for good tool life. The tool steels that we use in such an application would consist of either an AISI M2, M3 or M4 type of tool steel. The English equivalent of the AISI M3 tool steel would be the "Mushet Special" High Speed Steel VG produced by Samuel Osborn's, M3 made by Canadian Atlas, J. Edgar Allen (Attor M3), Jessop-Saville J13. These among others have a chemical analysis similar to the AISI M3 and would seem to have properties suitable for cold extrusion of steel. Characteristics of these steels are illustrated in chart form at the end of the Paper.

high wear resistance

On certain applications where high wear resistance is required due to an unfavourable configuration of the part to be extruded, we would use a tool steel of the high carbon, high chrome type. The AISI M3 tool steel properly heat treated would have a yield point in excess of 480,000 lb. p.s.i. and a hardness of Rockwell C65 to 67. This has been the practice at Verson and has been established as a successful one. The M3 type of tool steel is used quite prevalently for both the extrude punch, die, and anvil punch because of its excellent high yield strength and its red hardness which is sufficient for most applications. If a degree of toughness beyond that of the M3 steel is desired, then M2 and M4 steels are used.

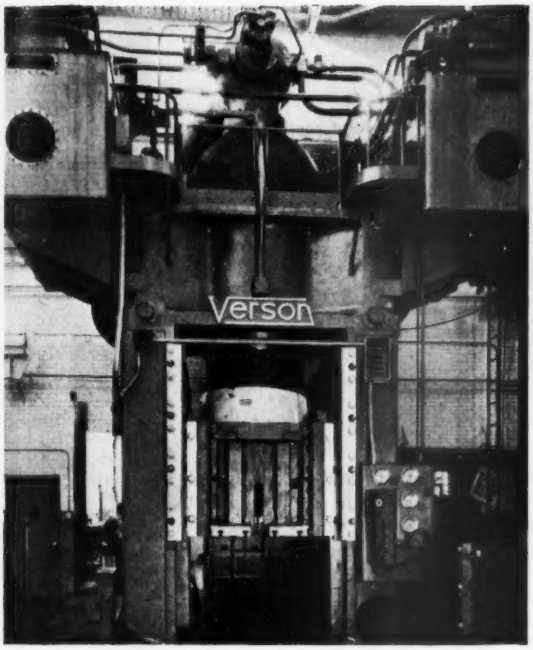
The slides shown with the Paper illustrated the typical tool stack, and at that time the salient points to be observed in its construction were pointed out. One of the most important points of tooling for cold extrusion is maintaining good alignment. At these high pressures it is essential to avoid having the punch deflecting in column. It must be guided both by the inherent characteristics of the press and the guiding characteristics of the die stack, so that the punch is not subjected to bending loads which result in early failure.



Typical dial type tooling set-up for high production automated cold extrusion work.

To do this, there are special requirements that must be adhered to in the construction of the press itself. It is our contention, proved in practice, that the press deflection on the columns during cold extrusion work must be held to a value roughly half that of a standard press design for sheet metal work. It must be strengthened in a bolster and sub-bolster construction so that the deflection of the structurals is kept to an absolute minimum. The press itself, if mechanical,

Close-up of mechanical press with dial type tooling in position.



A 3,000 ton hydraulic press for cold extrusion experimental work.

may be of a single point or double point suspension design depending on the type of tooling and operations to be included in the tooling. The upper and lower shoes of the tool stack are always guided by guide pins and close fitting bushings to control the last portion of the ram movement, so that the exact alignment of the punch and die and work piece can be maintained.

The tooling itself produces several types of basic cold extrusions and these may be produced singly or in combination for the manufacture of the piece part desired. Basically they may be divided up into the following classifications:

1. Backward extrusion, in which the plastic flow of the material is in opposition to the movement of the punch. In other words, the material moves in the opposite direction to the travel of the punch.
2. Forward extrusion, in which the material flow is in the same direction as the punch movement.
3. Coining, so that exact configurations can be maintained or altered to suit.
4. Drawing, which would be a conventional operation where the punch is pulling the material through a die and many of the other conventional metalworking terminologies that would apply to a series of operations in achieving a final piece part dimension.

low carbon steels

The ferrous material that can be extruded in practical tooling applications would include the very low carbon steels in the order of .08 to .10% carbon ranging up to and including a .30% carbon steel, which are commonly termed plain low carbon to medium carbon steel. However, there are certain alloying constituents that must be observed so that our extruding pressures do not exceed the practical limit of cold extrusion. Among these alloying constituents is silicon, which should be kept to a low value.

In American practice the silicon can range from a minimal value to as much as .30% Si. In the low carbon steel range it has been our practice to hold a silicon value of .15 to .20% in a fully aluminum killed steel. Also the manganese should be held between .60% and .80% where the carbon is on the high side. However, the very low carbon steels in the order of .10 to .12% carbon have been used with manganese contents up to and including 1.35% Mn. We must be aware that with this high manganese percentage in .20% to .30% carbon steels, the rate of cold working becomes so rapid that extrusion pressures are apt to be extremely high and the life of the tooling consequently shorter than with a lower carbon steel with less manganese and less silicon.

Steel of the carburising variety and a steel with .15 to .20% carbon have been used successfully. This includes the 5100 series, the 4600 series, 8600 series and in a few cases the 5000 series. There are certain matters to be considered in this range of carbon with these alloy steels. As we raise the nickel content, our initial extrusion pressures will be increased. The carbide formers in the usual ranges do not raise the initial pressures so rapidly as in the 5100 series and the 8600 series. The chromium in the 5100 series and the Cr.-Ni.-Mo. in the 8600 series, cause a slight increase in the extrusion pressure, but these steels can be very successfully extruded. Our starting hardnesses will range from Rockwell B70 to as much as Rockwell B85. The 4600 series presents a little tougher application for cold extrusion in that the higher nickel content reduces our chances of success with a minimum value in hardness and in strength. Nickel being a ferrite hardener does not respond to thermal treatment such as annealing for the soft extrudable structure desired. So it will be seen that in the 4600 series we are dealing with a steel in which the minimum hardness on a straight anneal would be Rockwell B80 to 85 and the characteristics of rapid work hardening. This steel is being used in various instances for the extrusion of roller bearing races and other similar applications where the real tough core for carburising is desired.

boron steels

Alloy steels of the hardenable variety with which we have had success would be of the AISI 4130 and the AISI 94B30 which is a boron type of steel with .30% carbon. These can be extruded, but are at present limited to a 50/55% reduction of area which can be accomplished with good tool life. Tool life must be expected to be somewhat more limited above

View of coating installation in the Company's Development Department.

the .30% carbon steels, alloyed or unalloyed. The .35% carbon to .40% carbon presents such high starting pressures that the impact resistance of the tooling is reflected in the lower endurance limit and more rapid fatiguing. This has been proved at Verson's to be impractical for economical high production cold extrusion. There are exceptions for special cases where the grain refinement and the enhanced physical properties are desirable and economical for those reasons alone.

Besides producing the geometrical form in cold extrusion, there are other advantages in the straight carbon material in that the cold working will improve the physical properties quite markedly, and has been utilised on some applications to achieve the final physical properties desired in the piece part. For a low carbon steel with a yield point of 35,000 to 38,000 lb. p.s.i. and ultimate strength in the order of 50,000 to 55,000 lb. p.s.i. and elongation value of 25% to 35%, cold working achieves an improvement in physical properties i.e. an ultimate strength of 91,000 to 96,000 lb. p.s.i., a yield point of 84,000 to 87,000 lb. p.s.i. and elongation value of 10 to 12% and a final hardness commensurate with these physical properties of Rockwell B95 to Rockwell B105. It is easily seen that this is a tremendous increase in physical properties and can be utilised as such in many applications for structural members. However, in most instances, in the manufacturing groups utilising cold extrusion, the carburising variety of steel, either plain carbon or an alloyed medium carbon steel, has been employed to produce a piece part configuration that is subsequently carburised and hardened for wearability and the desired physical properties.

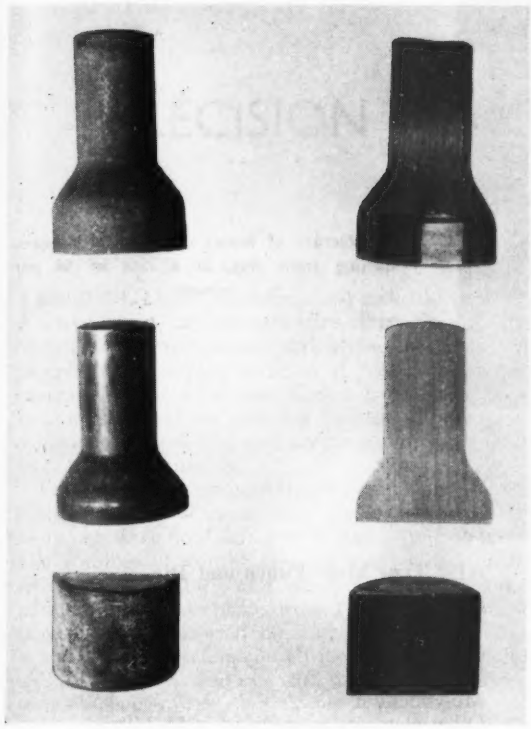
choice of presses

Presses used for cold extrusion must be designed for cold extrusion work and may be of several varieties, each having their own advantages. We may use a mechanical press of either a crank or eccentric type; in some cases a knuckle-joint press may be used for short high pressure strokes or we may use one of the hydraulic design. We have no individual preference as such at Verson's as we manufacture all these types of presses. The crank type mechanical press has been widely used for the reasons that it lends itself to high speed production and adaption of automated equipment both in the feeding of the material to the press, and the transfer of the material or slug from one station to the other until all operations have been performed. On longer pressure strokes, an eccentric press design would be used by us because of its advantages for alignment in the stroke of the ram and the structural reasons as compared with a crank type. This also lends itself quite readily to automated procedures like the mechanical crank type. If the production requirement or the productivity of equipment does not have to be high, a hydraulic press should be considered because the pressure stroke is long and the expensive drive of a mechanical press would not be necessary, and in such conditions the hydraulic press may have advantages from the point of view of economics.

From the above statements it is readily seen that all the available types of presses can be used for cold extrusion, and the main point in selecting a press is the type of cold extrusion work to be done. We maintain that where there are no special requirements as to long pressure strokes, the crank or the eccentric type mechanical press would be the proper selection for universal use.

an important aspect

We now come to one of the most important aspects of cold extrusion, which is the procurement of the slug for the extrusion itself. We have mentioned the basic materials in the relationship to extrusion. We must now consider cutting-off the slug into the proper diameter length and volume so that the extrusion will have the proper dimensions as required. The stock for the slug may be furnished from the mill in bar or coiled wire form. In general, the mill should furnish the material to meet cold heading quality specifications. This defines the surface quality to be free of seams, laps and detrimental subsurface inclusions. A steel meeting these requirements in most cases will be quite satisfactory for extrusion. The chemical analysis held within the AISI specification tolerances will be sufficient and not cause undue



Manufacture of propeller shaft end from slug, at a rate of 20 per minute.

variations in plastic flow properties. Internal defects should be held within the limits applied to good hot forging or cold heading practice. Marked centre porosity, piping and severe chemical segregation cause difficulties in cold extruding and should be checked in the course of acceptance of shipment from the mill.

In the range of low carbon steel with the carbon content up to .20% carbon, it has been found that a lamellar perlitic structure upon annealing is sufficient. This gives the best plastic properties commensurate with cost. A spheroidised structure can be produced and used, but the gain in better flow properties is not worth increased cost for the annealing procedures involved. Control of the diameter of the bar or wire is influenced by the degree of volume preciseness required in the extrude operation. It is directly controlled by the character of the shear fracture where shearing is employed. Where shearing is used as a cut-off means, we prefer to use the cold draw or cold finish diameter tolerances, plus or minus .002%. This allows the shear die to be made with minimum clearances for the bar and prevents excessive distortion in the cut-off and produces a cleaner break-off for shear surface. Bar can also be cut off by screw machines or saws.

It is important to realise that the surface produced by any of the methods must be good and clean; torn surfaces, burrs, deep tool marks and other excessive surface irregularities must be avoided. Such irregularities can, during extrusion, fold and be carried in the extrusion flow as a non-integral portion of the I.D. or the O.D. surface, producing an undesirable defect and because of their character cause a breakdown of the lube surface with consequent galling and seizing of the punch and die. When the slugs have been produced by machining or sawing, the O.D. may be to die size and used directly for extrusion after lube coating. If shearing has been employed the slugs should be headed to the proper O.D. and the ends squared. Heading of slugs prior to the extrude operation is not confined to sheared slugs alone. This may be applied with advantage to other types of cut-off methods. If hot rolled stock is used, heading will bring the O.D. to proper size in tolerance for the extrude die.

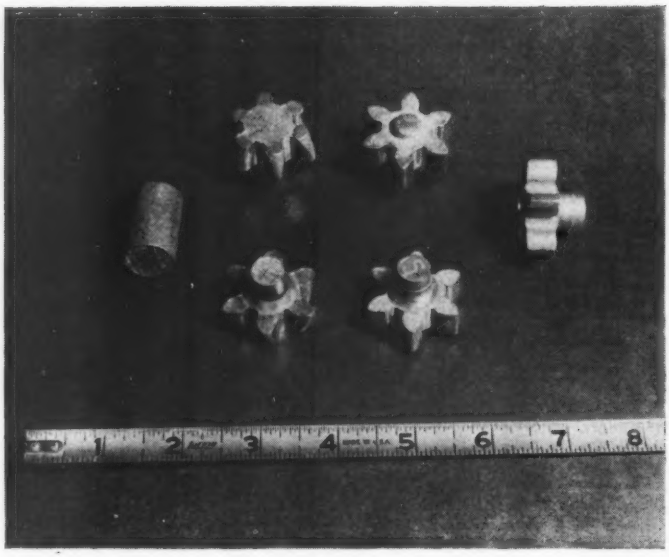
After heading is employed the cold work developed must be relieved by annealing. This will recover the ductility lost by the operation and reduce the hardness and the co-related starting pressures. The anneal may be of two types, one a high temperature anneal to recover the cold work and produce a lamellar pearlite structure; or two, a low temperature anneal at 1275 to 1325°F for a recrystallisation recovery anneal.

The following information details the various type tool steels used for extrusion:

1. **AISI Type M-2—Punch and Die**

Carbon	·80/ ·85%
Silicon	·20/ ·30%
Manganese	·20/ ·30%
Sulphur	·025% max.
Phosphorus	.025% max.
Tungsten	6·00/6·75%
Chromium	3·90/4·40%
Vanadium	1·75/2·05%
Molybdenum	4·75/5·25%
Temperature for forging	2050/1700°F
„ „ annealing	1550/1600°F
„ „ pre-heating	1400/1500°F
„ „ hardening	2180/2250°F
„ „ tempering	1000/1150°F

Generally is austenitised at 2200°F and tempered at 1050/1100°F for maximum toughness at Rc 62/64.



Manufacture of motor car door lock gears, starting from slug, at a rate of 54 per minute.

2. **AISI Type M-3—Punch and Die**

Carbon	1·20%
Tungsten	6·00%
Chromium	4·10%
Vanadium	3·20%
Molybdenum	6·00%

Other elements as specified in M-2 Type

Temperature for forging	2050/2080°F
„ „ annealing	1550/1600°F
„ „ pre-heating	1450/1550°F
„ „ hardening	2200/2250°F
„ „ tempering	1000/1100°F

Practice is to quench from 2175/2200°F in oil and draw at 1050°F for maximum hardness of Rc 65/67.

3. **AISI Type M-4—Punch and Die**

Carbon	1·27%
Tungsten	5·50%
Chromium	4·50%
Vanadium	4·00%
Molybdenum	4·50%

Other elements as specified in M-2 Type.

Temperature for forging	2050/1700°F
„ „ annealing	1600°F
„ „ pre-heating	1400/1500°F
„ „ hardening	2175/2250°F
„ „ tempering	900/1200°F

Practice is to quench from 2200°F in oil and draw at 1050°F for a hardness of Rc 64/65.

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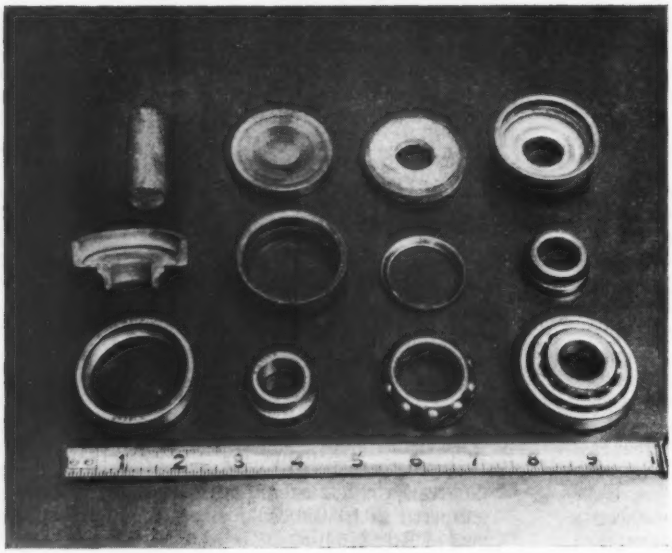

Manufacture of inner and outer bearing races by cold extrusion, starting from slug.

PRECISION FORGING OF STEEL SHAFTS

by ROBERT SPECK, A.M.I.Prod.E.

PRODUCTION engineers must seek constantly to save costs in manufacture through reducing material consumption and simplifying metal working procedure by keeping removal of metal by machine processes to the minimum, and it is probably today true to say that by securing precision forged steel components, more real cost saving is possible than by any other single means.

Further, and apart from thereby achieving the most economical use of costly steel alloys, it has become more necessary now than ever before—vital, in fact—that forgings be consistently accurate dimensionally, free from flashline, and conform regularly to a pattern, for it is only in this way that proper functioning can be assured of automatic machine tools equipped with mechanical self-loading and unloading aids, frequently linked one with another by workpiece transfer devices.

To these ends great strides forward have been made during the past ten years by designers of forging plant in producing profiled parts of both simple and complicated forms—bevel toothed and internal toothed gears combined, with adjacent forms and projections included, for example, which hitherto would have been quite out of the question, requiring manufacture as individual items to be machined separately for assembly together at later stages. A wide variety of such forgings can now be produced quickly to accurate dimensions, and consistently to a weight within 2% or 3% of the finished machined article, so achieving material economies to the order of 30% and even 50% by weight alone, in comparison with normal stampings.

To this must be added the considerable saving of many costly man and machine hours; savings accruing from reductions in transportation charges through

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PRESSURE ECONOMY — concluded from facing page

4. **AISI Type D-7—Punches**

High Carbon—High Chromium

Carbon	2·30%
Chromium	12·50%
Vanadium	4·00%
Molybdenum	1·10%

Other elements as specified in M-2 Type.

Temperature for forging	2050/2100°F
„ „ annealing	1600/1650°F
„ „ pre-heating	1400/1450°F
„ „ hardening	1900/2000°F
„ „ tempering	350/ 400°F

Practice is to quench from 1900°F in air and draw at 375°F for a hardness of Rc 62/64.

5. **AISI Type H-12—Shrink Rings**

Carbon	·35%
Silicon	1·00%
Chromium	5·00%
Tungsten	1·20%
Vanadium	·35%
Molybdenum	1·45%
Temperature for forging	1600/1950°F
„ „ annealing	1650°F
„ „ pre-heating	1200°F
„ „ hardening	1825/1850°F
„ „ tempering	1000/1200°F

Practice is to quench from 1850°F in air and draw at 1050°F for a hardness of Rc 48/52.

Comparable Grades to AISI M-3 Tool Steel

Samuel Osborn & Co. Ltd.,
Clyde Steel Works—Sheffield.
" Mushet Special " High Speed Steel V G.
1·55 C
6·5 W
4·75
5·0 V
3·0 Mo.
5·0 Co.

Pre-heat	800/ 850°C
Forge	1110/1120/°C
Anneal	850/ 900°C
Hardening	1200/1220°F

Oil quench or air.

Tempering 3 periods of 1 hour at 540°C.
Rockwell C 66/68.
Canadian Atlas M-3 type steel.
Edgar Allen—Sheffield—M-3 type.

The practice on all the high speed steels has been to triple draw. This gives maximum structure stability and reduces retained austenite to a minimum. It is also good practice to double-draw the D-7 and H-12 steels for the same reasons.

Example of a precision hammer forging machine of vertical construction.

reduced weights and bulks; much lower consumption of expensive cutting tool alloys in machining; smaller horse power consumption in machining; far less wear and tear on machine tools, much reduced swarf production and handling costs thereof; and, by no means the least factor, greatly improved handling during machine loading, inter machine transfer, and inspection.

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Following an apprenticeship with the B.S.A. Machine Tool Group, Mr. Speck joined E. H. Jones Ltd. and, later, Messrs. Drummond-Asquith.

In 1954 he founded his own Company, Robert Speck (Machine Tools) Ltd., who represent Louis de Roll, S.A., of Berne, and have been responsible also for design and development of the Centrumatic range of face milling and centring machines.

Mr. Speck is also a Director of Acton Bolt Ltd.

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some remarkable facts

The facts of these matters are truly remarkable and warrant closest investigation by all engineers concerned with small and medium as well as large quantity batch production of steel alloy components.

This Paper is concerned particularly with possibilities of plant for producing multiple diameter shaft components by these precision forging methods, which can be done now in floor-to-floor times considerably shorter generally than those required for the rough machining only of conventional forgings. Rough machining can be practically eliminated very often by these new processes, leaving finishing to be done by light turning, milling and grinding operations.

Truly round and straight multiple diameter shafts, parallel or tapered, and at times incorporating special forms, are produced from hot steel billets in floor-to-floor times shorter by far than most other methods, including turning from the bar; and with dimensional accuracies to the order of plus or minus 0.010 in. diametrically and between shoulder faces. Moreover, these forgings have no flashline whatsoever and thus is eliminated one of the biggest headaches to both forgemen and machinists, especially those concerned with the use of automatic machine tools, tooled with special work holding fixtures.

Foremost in this field is the type of forging machine incorporating multiple hammers of simple pattern and profile arranged to reciprocate at high speed, whilst a billet of heated steel is passed automatically between them to be swaged down to a preset pattern of diameters and lengths. Contrary to normal upsetting methods this particular process of precision forging reduces material from large to smaller cross-sectional areas, whilst at the same time stretching it longitudinally. This technique is distinguished from the usual methods of forging in the following principal respects.

saving in floor space

Firstly, as the required total reductions of size in a piece are achieved with a series of swaging operations carried out at high speed by a method dividing the forging forces between a multiplicity of small blows, the designers have been able to build machines comparatively small in bulk and weight in relation to the size of components they can process. Much less shop floor space is needed for this type of plant in comparison with other methods.

Secondly, the finished form of the piece is not governed by the shape of the dies only, as is usual, but also through the medium of adjustable stops, and, in certain instances, templates. In this way it is possible now to produce forgings over a wide range of diameters and lengths using only one set of simple and inexpensive tools. The change over from one size of workpiece to any other is simple and the procedure similar to that for setting up an automatic chucking or turret lathe. Because of its comparative simplicity, small batch quantities can often be produced as forgings which could not possibly be justified

by the costs of die manufacture necessary for other forging methods to be used.

outstanding accuracy

Thirdly, the dimensional accuracies of finished forgings together with the speeds of production obtained are outstanding. Tolerances of plus or minus 0.010in. are guaranteed for diameters up to 2½ in. and straightness to within $\frac{1}{16}$ in. for lengths up to, say, 24 in., whilst for diameters and lengths larger and longer, dimensional allowances are relatively very little different. One can control exactly the amount of material to be left on any diameter at any position on the workpiece.

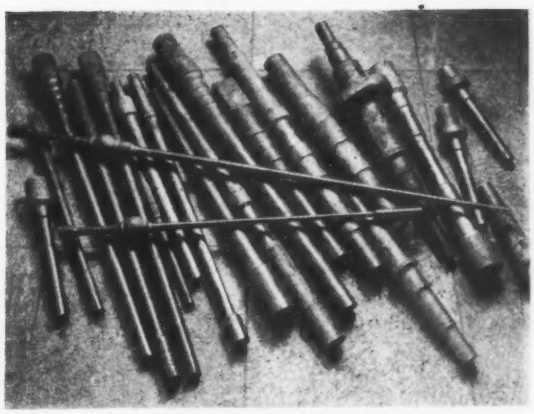
At the same time, surface finish appearance can be smooth enough to permit machining to be dispensed with altogether where it is not a bearing surface, and therefore strictly necessary. The processing of automobile axle transmission shafts in particular has been much simplified because of this.

The process was developed at first for round material sections only but machines are being built now for handling square, rectangular and polygon sections, with equal facility. For certain ranges of work machines of vertical construction are the most satisfactory, whilst for heavy section materials, horizontal construction is favoured. Whichever is employed, however, the general construction and principles of operation are similar and either style of machine can be installed without provision of elaborate foundations of the depth and solidity demanded by conventional stamping machines. In fact, plant of this nature can be regarded as precision machine tool equipment for installation alongside lathes and milling machines, upon which it will have no adverse effect through vibration, noise, general inconvenience, or any other undesirable aspect.

As mentioned earlier, with this style of machine a pre-heated billet is loaded into and held by a chuck during processing. The chuck is air-operated and motor-driven to rotate the billet whilst feeding it automatically through the reciprocating forging hammers arranged symmetrically around the work. The construction of this chuck is such that all forces exerted upon it are absorbed by spring cushions and special rubber pads to eliminate vibration. Protection for hammers against accidental working also is provided through special replaceable shear plates incorporated in the driving mechanism assemblies, one for each hammer.

The principal part of the machine is the forging box, containing reciprocating shafts driven from fast running eccentric bushes and transmitting their movements through guided connecting rods directly to their respective forging hammers.

These reciprocating shafts, three or four according to the type of machine employed, are arranged symmetrically about the work as already stated and their movements are synchronised so that the forging



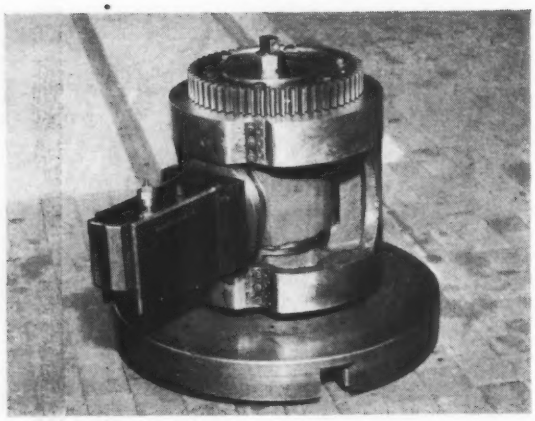
Examples of precision hammer forged shafts.

actions take place at all points on the same axis at the same time.

In this manner the forging blows are brought into equilibrium and the machine foundations not affected by transmitted vibrations. The forging box is heavy and rigid in construction to withstand the continuous hammering, and the guides of the hammer connecting rods are specially designed to avoid separate bearings between the eccentric rods and the ends carrying the hammers. The number of main bearings has thereby been kept to the minimum, the whole construction simplified, and speeds of operation so increased as to be far in excess of those possible by alternative methods of equal working capacity.

Shafts are pressure-lubricated, guides water-cooled, and hammers air-cooled, to extract as effectively as possible the heat absorbed from billets. It is interesting to note in this respect that temperatures for forging by these methods average about 100° less than

View showing finish precision forged shaft gripped by chuck and being withdrawn vertically from the hammers.



Precision hammer block and eccentric drive head.

those necessary for other methods, and that maintenance of a set temperature is not critical. This greatly assists in keeping down furnace operating costs and contributes directly to prevention of scale formation, which in turn is a most important factor affecting forging tool life and the good surface finishes that are obtained by these methods.

automatic controls

The system of cycle control used is primarily hydraulic. It is fully automatic in operation and once a forging cycle has been started it continues until the work is completed. Except for starting of the machine, an operator's only responsibilities are the loading and unloading of billets and finished pieces for each cycle.

The automatic controls provide for the following functions: (a) radial setting of hammers to accord with diameters to be forged; (b) axial traverse of work to accord with lengths required between shoulders of the respective diameters; (c) changes of work traverse speeds and forging hammer in feeds in relation to step reductions made; and finally (d) withdrawal of work from the hammers and stopping of the machine ready for unloading.

The various diameters and lengths are set by means of stops on horizontal and vertical cycle control drums within the main frame of the machine, the hydraulic control system being arranged in such a manner that diameters and corresponding lengths between shoulders are forged successively in a single cycle.

Through adjustable throttle valves controlled from trips on these drums, forging speeds are chosen automatically to be selected in accordance with surface finish qualities required for the different diameters.

Again, as mentioned earlier, tapered diameters can be included in the same cycle as parallel diameters. This is achieved through the medium of a simple template mounted within the body of the machine and having an angle of taper corresponding with that of the work. In operation this template takes over functions of the normal stops and allows the forging hammers to feed in progressively as a billet passes through them. At the end of the taper section normal working is resumed as for parallel diameters, and without attention in any way from the machine minder. The maximum included angle of taper possible is about 20°.

further possibilities

Further possibilities are for direct in-forming of profiles, round in section although not necessarily symmetrical in form—such parts as ball steering pins, valve stems, rocker operating rods, short multi-diameter shafts and like pieces. These can be made in 'sticks' or multiples and left as one shaft for subsequent turning, before heat treatment. Afterwards they can be separated by sawing off or shearing. Forging tools for such pieces are restricted generally to the particular parts for which they have been made and are not suitable usually for any other pieces.

Actual forging times achieved by these types of machines depend upon work traverse speeds, in feeding to depth times for the hammers and machine idle movement times, these in turn being decided chiefly from the nature of the surface finishes required.

Naturally times can be varied considerably therefore but, as a general guide, one would expect for shaft of diameter between one and four inches, and length from six to forty inches, that times would range approximately between 20 seconds and 120 to 180 seconds. These would be floor-to-floor times for an average six or seven diameter shaft.

Sequence of operational working and the various feeds to be used will be decided by the production layout department when drawing up working schemes. This procedure is simple and akin to preparation of any tooling layout, and ensures the machine will work to best advantage and under controlled conditions at all times.

Normally any number of diameters up to about seven can be produced in a single and uninterrupted cycle, but when the two shaft ends are smaller than the centre or one other diameter, it will be necessary then for the cycle to be interrupted at a suitable point, the part reversed and the cycle re-started to be completed. On the other hand, if the two ends are symmetrical from the centre, then fourteen or so diameters could be completed by this reversal procedure.

Of course, an alternative method is to use two distinct settings, changing over for the second end upon completion of the batch run on the first end.

Which is most economical will be determined usually by the quantities involved and whether or not a re-heat is necessary, this being decided by the volume of the piece and cycle time for the first operation. In the majority of cases pieces can be completed in a single heat. The choice of methods will depend also, of course, upon whether more than one machine is available.

(*concluded on page* 335)

THE FLUID-FORM PROCESS

by HUGO MÖLLER

Chief Tool Designer,
Car Division,
Svenska Aeroplan Aktiebolaget,
Sweden.

IN different countries, for many years, methods for plastic forming of sheet have been worked out by which some of the tool parts, preferably the die, have been made of a flexible material, usually rubber.

The many patents existing in this field prove the widespread interest in this subject, although a large number of such devices protected by patents may be characterised as "pipe-dreams" which have never found commercial application.

The method used in practice consists, without exception, of special presses which have limited range of use and in addition are very expensive. We are often confronted with the problem of forming sheet metal blanks into intricately-shaped parts in small quantities, or for experimental purposes, of which the cost of tool-making, and the time required for manufacturing of tools, constitutes a major portion of the cost of production.

Manufacturers of such sheet components have generally an opportunity of using conventional presses, single- or double-acting, with press power of 300 tons and more, but are restricted to the use of conventional press tools with punch, blankholder and die.

At Svenska Aeroplan Aktiebolaget (SAAB), who manufacture cars, aircraft, and parts for jet engines, we often meet with complicated sheet parts of different kinds, which must be manufactured at short notice, sometimes for experimental purposes and sometimes for serial production in low and medium quantities. For such purposes, Svenska Aeroplan Aktiebolaget have worked out the so-called Fluid-Form attachment, intended for fitting on conventional presses. The Fluid-Form, which is protected by patent, or for which patent is applied for in all industrial countries of importance, should be of interest to other manufacturers with similar production.

For manufacturers of components of intricate shape, the ever-present question is: "how to produce this part in the best technical and most economical way?" At SAAB the Fluid-Form has often been the answer.

If a blank is to be given an irregular shape through plastic forming, this can be done in a simple tool, made with a cavity, the shape of which corresponds to the shape of the finished part, and with a flexible punch, which also works as blankholder. The punch must be able to adopt the shape of the cavity of the tool and exert such a high pressure on the blank placed between the die and the punch that the yield strength in the blank is exceeded, and the sheet adopts the shape of the cavity at the same time as the punch also prevents wrinkles in the sheet by exerting a sufficient pressure on the blank.

The component shown in Fig. 1, belonging to a jet engine, led to the Fluid-Form idea. In accordance with the drawing, this part should preferably be manufactured in one piece, but in a note on the drawing it was mentioned that a fabricated method was also acceptable.

If it were possible to press the part in one piece, we should get a better performance from the production point of view, with fewer parts and tools and less manual work. In addition, the welding would be eliminated. This component is, however, of such a shape that it cannot without great difficulties be pressed in one piece in accordance with conventional methods with a rigid punch. The necessity of using a flexible punch which could exert a sufficient specific pressure against the sheet blank, so that the blank and the punch were shaped to an underlying rigid and split die, was very obvious. Further, it was necessary that the conventional rigid blankholder could be replaced by the flexible punch, which could give an equally distributed blankholder pressure.

When pressing parts with irregular shape, the flexible punch could give additional advantages.

Fig. 2 shows the "contact picture" against the blank at a rigid punch when pressing an irregular part in a draw tool of conventional type.

In the free sheet surface within the "contact area" and the die, the deformation of the material cannot be controlled and unwanted deformations occur in the sheet blank in the form of buckles, which, if the surplus material is too large, may be retained in the finished part.

Fig. 3 shows the corresponding "contact picture" with a flexible punch. Here there are no free sheet surfaces, since the punch covers the whole blank in this method. The forming starts over the entire die opening at the beginning of the forming operation as distinguished from the rigid punch, which first contacts the sheet blank at the points where the draw depth is greatest. The forming with the flexible punch is completed gradually, so that the shallow sections are shaped first, after which these areas serve as blankholder areas whilst the deep sections are formed.

The flexible punch must be able to change its shape to a considerable extent in all directions, in order to fill the volume of the quite large cavity, at the same time extending sufficient pressure to exceed the yield strength of the material to be shaped. When this pressure reaches 800 kg./cm.^{2} (11,375 psi.) which is required for forming certain types as is used for stainless and heat resisting materials, e.g., stainless 18-8 and Nimonic 80 between 24-19 SWG in thickness, the punch cannot be made of solid rubber if extensive deformation is required. The necessary flexibility, however, can be obtained through a combination of rubber and a fluid.

Fig. 1.

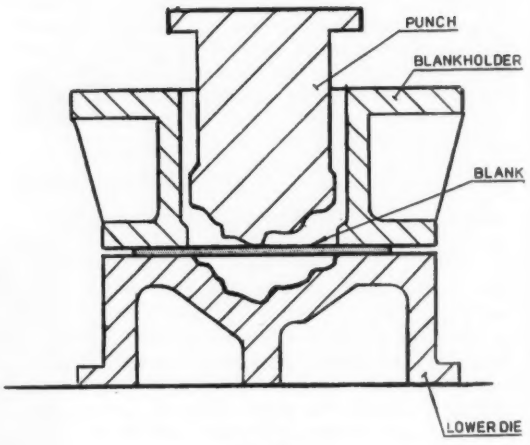


Fig. 2.

It is thus possible to form irregular shaped parts in a simple tool having a cavity in a shape corresponding to the outer contour of the finished part and with a flexible punch usable for all parts within the range of certain sizes. This device is diagrammatically shown in Fig. 3.

The flexible punch consists of a cylinder with a telescoping piston. The lower opening of the cylinder is closed by a rubber diaphram and the space between piston and diaphram is filled with oil. This unit, which is to be fitted in the press slide, thus forms a standard unit, which can be used for manufacturing of different parts of certain sizes.

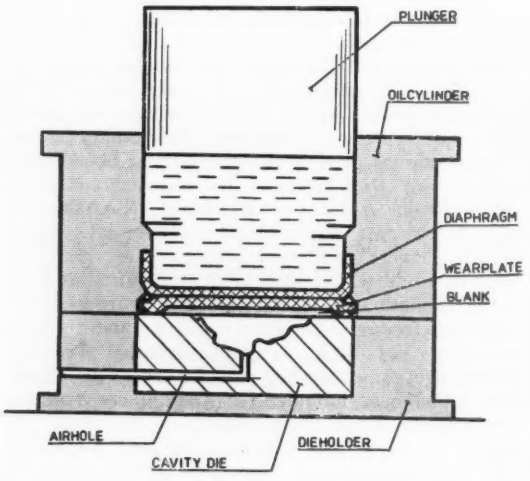


Fig. 3.

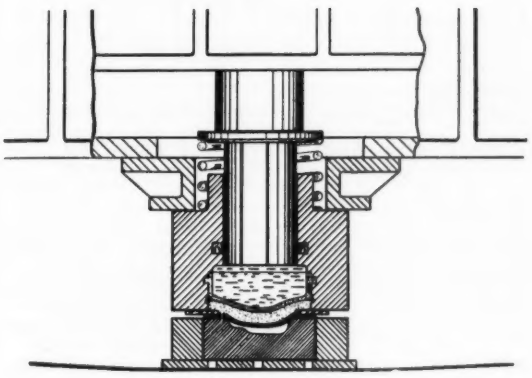


Fig. 4.

The diameter of the rubber diaphram is determined by the available press power, so that the necessary specific fluid pressure can be obtained in the cylinder. The tool, fitted in the holder on the press bolster, is comparatively simple and cheap to manufacture. It consists principally of a round die with a cavity corresponding to the other contour of the finished part.

A test unit intended for use in double-acting 350 - 225 ton mechanical presses was manufactured in accordance with these principles. To make it possible to use the total press power and to obtain maximum diaphragm diameter, the unit was designed as shown in Fig. 4.

The diaphragm diameter D was dimensioned for the total press power from the inner and outer slide of 350 + 225 = 575 tons, and the piston diameter d for the power press of the inner slide only, by which the up-acting pressure against the ring-shaped surface

$$\frac{\pi}{4}(D^2 - d^2)$$

was held against the outer slide.

Some dies with comparatively simple cavity shape were manufactured and tested. The result was very successful, and therefore the experiments proceeded with more and more complicated cavity shapes at the same time as certain improvements were made. Among other things, a protective rubber diaphragm was designed for the purpose of protecting the sealing diaphragm from wear and damages by cutting. This protective diaphragm consists of a round rubber plate, which is fixed in a groove in the pressure chamber and can be changed in a matter of moments.

This protective diaphragm is an almost 100% protection of the sealing diaphragm, which rarely has to be changed, since the protective diaphragm takes all the wear. The life of this protective diaphragm depends to a great extent on the shape of the tool cavity. Approximately 4,000 - 5,000 pieces can be pressed in dies with simple cavity shapes without a change of diaphragm.

At first the Fluid-Form was used at SAAB for manufacturing experimental components for aircraft and jet engines. As the technique was further developed, the method was successfully applied to the manufacture of more and more complicated pieces. Now, practically all components with intricate shapes for aircraft and jet engines, as well as test and experimental components for SAAB's other products, are manufactured in Fluid-Form attachments. Seven units with diaphragm diameter between $4\frac{1}{2}$ in. - $19\frac{3}{4}$ in. for presses between 100 - 1,000 tons are now in use in our company.

The method is also suitable for large production runs, proved by the fact that a Swedish company has produced as many as 200,000 pieces per year of a special component made by the Fluid-Form process in a 100 ton press. More than 500,000 pieces have been made up-to-date by this method.

Fig. 5 shows this component, which originally was planned to be draw-pressed in a tool with rigid punch and blankholder and to be trimmed afterwards. Owing to the saddle-shape of the part it was impossible to avoid wrinkles and the part was also very difficult to trim. This latter operation has to be undertaken in several steps. The waste of material was also very great, as more than 70% was lost in blankholder scrap.

By the use of the Fluid-Form the component could be pressed in one step from a contour trimmed blank, requiring no trim afterwards.

The weight of the blank, which was 140 gr. when pressed in a rigid tool, was only 30 gr. when formed in the Fluid-Form, and 22 tons of sheet could thus be saved each year. Parts of this type with even lines and comparatively large radii do not require such a high specific fluid pressure (800 kp/cm²) as mentioned before. High fluid pressures are, however, necessary in order to make embossings and small bottom radii.

Practical experiments have proved that it is possible to obtain the following bottom radii at a constant fluid pressure of 750 kg./cm.² (10,600 psi.). (Table I.) In cases where exceptionally small radii are required, these can be obtained in a way that will be described later on in this Paper.

The size of the attachment, the diaphragm diameter, is first of all determined by the available press power. The Fluid-Form aggregate can be used on presses with a press power of between 10 - 3,000 tons.

Fig. 5.

TABLE I

Nimonic 75	Stainless 18-8	Car body sheet	Mg-Si-Aluminium soft
$r_i = 10.t$	$r_i = 7.t$	$r_i = 4{,}5.t$	$r_i = 2{,}5.t$

r_i = inner bottom radius, t = sheet thickness in mm.

RELATION BETWEEN DIAMETER OF DIAPHRAGM AND PRESS CAPACITY

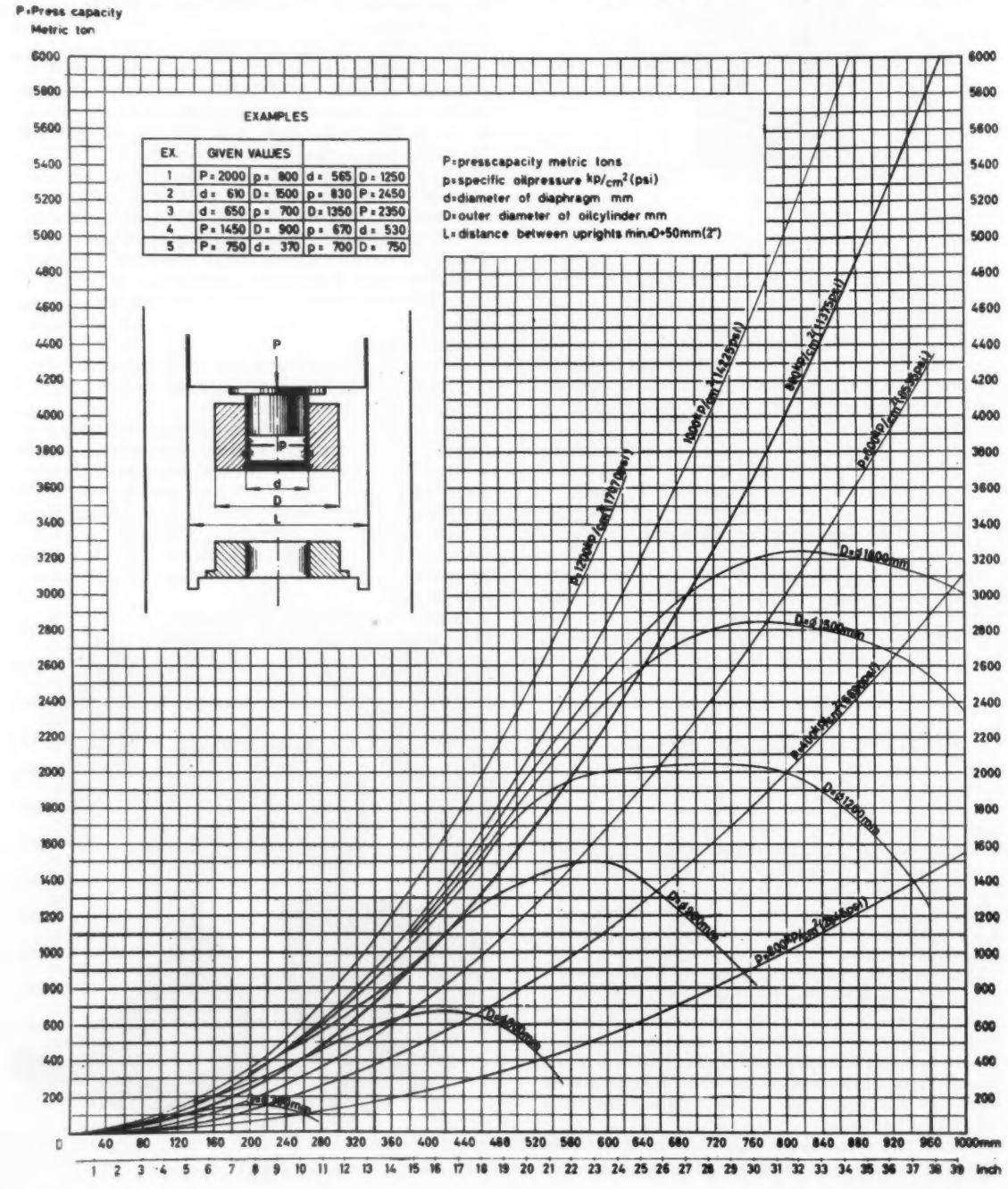

P=Press capacity
Metric ton
EXAMPLES
EX. | GIVEN VALUES
1 | P = 2000 | p = 800 | d = 565 | D = 1250
2 | d = 610 | D = 1500 | p = 830 | P = 2450
3 | d = 650 | p = 700 | D = 1350 | P = 2350
4 | P = 1450 | D = 900 | p = 670 | d = 530
5 | P = 750 | d = 370 | p = 700 | D = 750
P=presscapacity metric tons
p=specific oilpressure kp/cm² (psi)
d=diameter of diaphragm mm
D=outer diameter of oilcylinder mm
L=distance between uprights min.D+50mm(2")
P
p
d
D
L
D=1800mm
D=1500mm
D=1200mm
D=900mm
D=600mm
D=300mm
d=Diameter of diaphragm

Fig. 6.

The diagram in Fig. 6 shows the relation between the diaphragm diameter d and the press power P and gives an idea of the maximum outer diameter D of the attachment at different specific fluid pressures p. From this diagram it is evident that, at a specific fluid pressure p of, for instance, 800 kg./cm.^{2} (11,375 psi.), a 100 ton press gives a diaphragm diameter d of 125 mm. (5 in.) and a 3,000 ton press gives a diaphragm diameter d of 690 mm. (about 27 in.).

For double-acting presses the total press power of the inner and outer slides is considered to be the press power P in the diagram in Fig. 6.

Fig. 7 shows a schematic operation cycle for Fluid-Form, where the diaphragm acts as a flexible punch in a tool with cavity.

With the aid of a hydro-pneumatic cushion in the press bed on a single-acting hydraulic press, the Fluid-Form attachment can be used for a rigid punch, by which the diaphragm acts as a flexible die.

Fig. 8 shows such a design schematically and Fig. 9 the operation cycle.

The former method (Fig. 7) is intended for manufacture of components with intricate and irregular shapes and for components with undercut, in which case split dies are used. The latter method is mainly intended for comparatively deep and symmetrical parts. In this case, two tool parts are required, namely, punch and blankholder.

With the aid of a control valve built-in to the hydro-pneumatic cushion, the counter pressure at

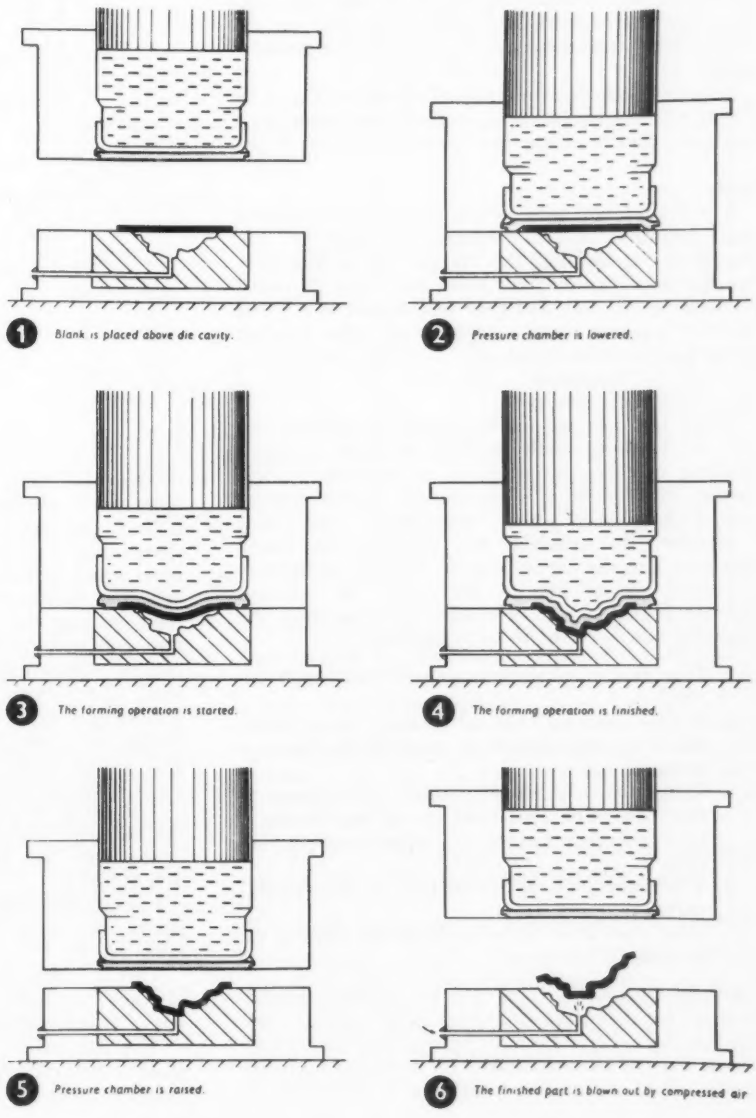

1 Blank is placed above die cavity.
2 Pressure chamber is lowered.
3 The forming operation is started.
4 The forming operation is finished.
5 Pressure chamber is raised.
6 The finished part is blown out by compressed air

Fig. 7.
Operating cycle.

the downward movement of the cushion can be varied. This means that the blankholder pressure can be varied during the working cycle, so that, for instance, we have a high pressure at the beginning of the stroke and a low pressure at the end or *vice versa*. In other words, we can adjust the pressure of the blankholder during the working cycle, so that the lowest required pressure of the blankholder is always used.

As mentioned above, presses of between 100 - 3,000 tons are suitable for use in combination with the Fluid-Form attachment. An hydraulic press is preferable, owing to the fact that it can be operated to return at a predetermined pressure, i.e., the press can be run down to a pressure, which is fixed beforehand, independently of the position of the slide. Further, the hydraulic press has the advantage over others that the pressure on the press slide and consequently the pressure in the fluid chamber on the Fluid-Form attachment can be read on the pressure gauge.

A prerequisite for the method shown in Fig. 8, is a single-acting mechanical or hydraulic press or a hydraulic double-acting press with connected slides.

tools

The Fluid-Form tools, dependent on the number of parts required and the degree of difficulty encountered in forming the component in question, can be manufactured of steel, cast iron, Kirksite, plastic or hardwood, and generally consist of a round die with a cavity corresponding to the other contour of the part, or of a punch and a blankholder ring.

A. dies with cavity

When the dies are manufactured of steel or cast iron, the cavity is usually worked up in an automatic profiling machine according to an accurately made pattern, since there is no springback in the pressed part. The necessary surface smoothness in the cavity is obtained by grinding and polishing by hand. Standard size die blocks can be stocked completely machined, except for the die cavity. In selection between steel, cast iron or plastics for press tools, the following points ought to be considered :-

1. How many components will be made with the tool?
2. Is this piece suitable for forming in a plastics tool with regard to shape, material, thickness of material, etc?
3. If the tool is made of plastics, is the shape of the piece such that steel inserts are necessary on special points in the tool where wearing may occur?
4. What tolerances are to be held on the finished part?
5. How soon does the finished article have to be available?

Polyester plastic has proved to be the most suitable material for manufacturing tools to be used in combination with Fluid-Form. The dies are made with a glass fibre reinforced coating on a core of polyester plastic mixed with filling compound.

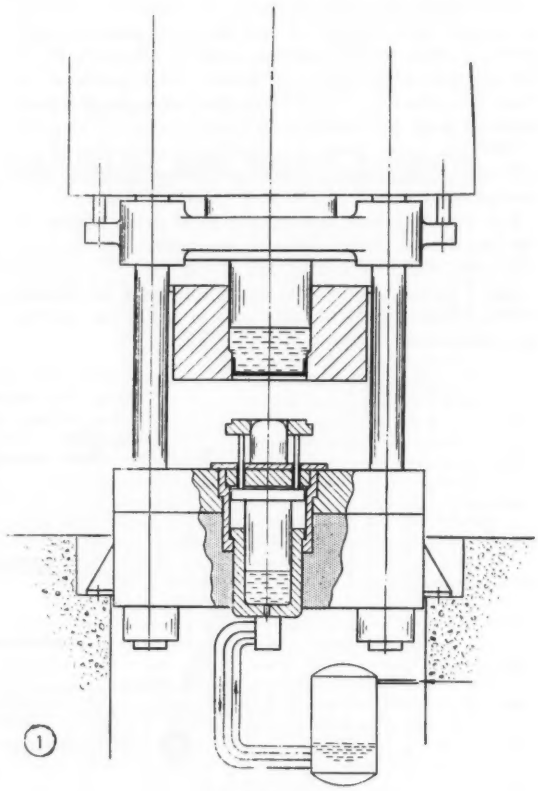


Fig. 8.

The glass fibre coat, usually consisting of four glass webs, is formed separately over a model of plastics, gypsum or wood. This glass fibre coat is covered by a plastics foil as separating coat for the core, which is then cast on the plastics foil. When the core has hardened and shrunk, the plastics foil is removed and the core is cast solid against the glass fibre coat with a thin layer of plastics. The machining can be eliminated if the core is made a little too small in the casting and the missing material, in the bottom of the die and on the outer diameter, is added by the last casting being done against a surface plate and a steel form, which gives strictly the required outer diameter of the die.

The life of a plastics tool of this type depends on the material which is to be formed and the shape of the piece, but 500 - 2,000 pieces can be mentioned as a guide.

Components with undercut can be made in a cavity tool using a die which is split into two or more pieces.

This is illustrated in Fig. 10. Such split dies can of course be made of the above mentioned materials, steel, cast iron, Kirksite, plastics material or hardwood.

The particular die shown in Fig. 10 is made of plastics material. When a split die is used, it must be removed from the holder ring after each press stroke.

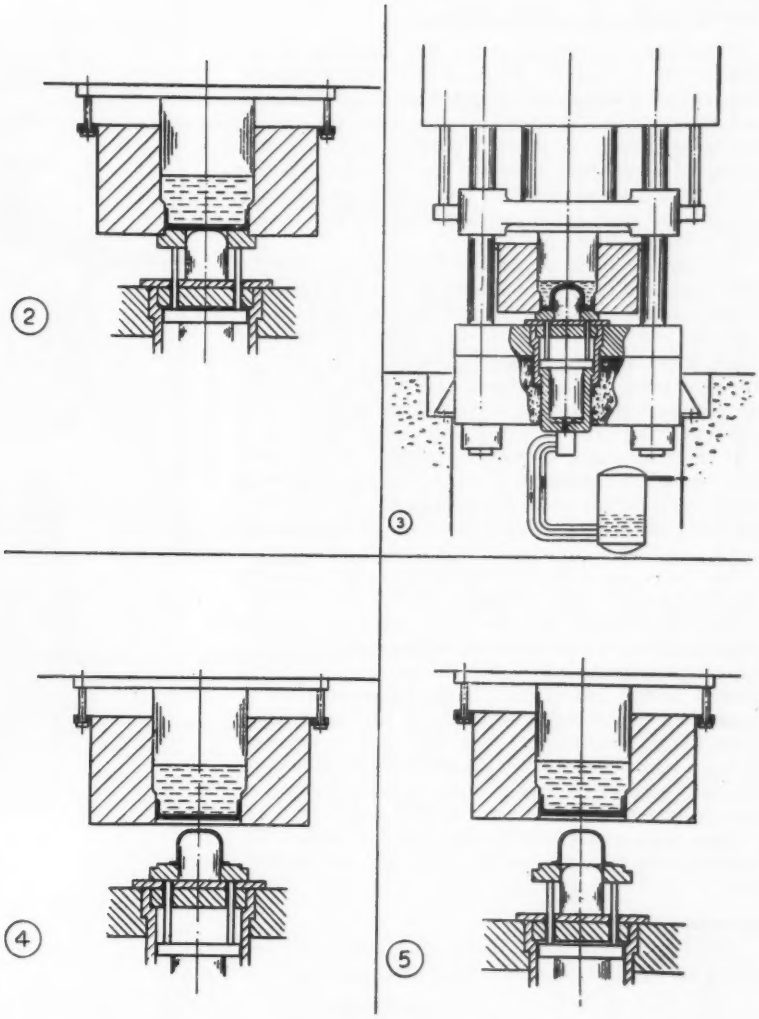


Fig. 9.

as shown in Fig. 10, so that it can be taken apart and the pressed part removed. For this purpose the press should be provided with an air cushion or other ejector device. In tools with large cavity volume, it may be necessary to carry out the press operation in more than one stroke with intermediate annealing of the part. In such cases, the volume of the depression in the material during the first operation should be filled with a piece of rubber or similar material (see Fig. 11), as otherwise the air volume hemmed in by the rubber wear plate will be compressed and may involve a risk of burning the diaphragm.

The air volume hemmed in by the blank in the tool cavity is carried off through one or more air holes (see Fig. 11), whose diameter must not exceed the double sheet thickness. The number of holes must be sufficient to allow the air to be vented quickly.

These air holes can also be used for ejecting pieces by means of compressed air (see Fig. 7, picture 6).

The practical results obtained in forming the bottom radii for different materials have been stated in Table I. If small radii or special sharp bottom corners are required, these can be obtained by an additional operation in the same die by placing a special edging piece of harder material in the prepressed stamping, so that a concentrated pressure is obtained on the sections which require sharp corners (see Fig. 12).

Plastics or Kirksite, cast directly in the die cavity, are suitable materials for such an edging piece.

B. tools consisting of punch and blankholder

Such tools are used as shown in Figs. 8 and 9. The punch is made of plastics or cast iron owing to the number of pieces to be made and their shape. For components made of aluminium and hardwood can also be used in the punch. The blankholder is made of cast iron.

how to make use of Fluid-Form

It has been mentioned earlier that the Fluid-Form attachment is mainly intended for manufacturing complicated components or irregular shapes in small and medium-sized production runs, with the aid of simple tools made of steel or plastics material, consisting of a die with a cavity corresponding to the shape of the component, or for comparatively deep components with a tool consisting of a rigid punch and a blankholder ring.

For certain types of components, the number of operations and tools can be reduced by a combination of conventional tools with rigid punch, blankholder and die and a Fluid-Form die. Thus, components which give an unfavourable "contact picture" for the rigid punch in a conventional tool (see Fig. 13a) are pressed preparatory in a Fluid-Form die (Fig. 13b) and then completed in a conventional tool (Fig. 13c).

If the diaphragm is replaced with a rubber sack, the Fluid-Form attachment can be used for expanding of components as shown in Figs. 14 and 15. Here the sheet metal blank may consist of a draw pressed blank with bottom or a rolled and welded sheet strip.

Fig. 16 shows a Fluid-Form attachment in which the die has been replaced by a rubber sack.

The Fluid-Form can also save time and money when used for manufacturing experimental and/or test components for car bodies, refrigerators, electrical kitchen ranges, etc. Usually such components are so large that they cannot be made in one piece in a Fluid-Form attachment, as the case will be later on in mass production by conventional tools. However, for test purposes such parts may be made in two or more pieces, which are then welded together.

Door panels and fenders for test car bodies, for instance, can be made quickly in simple tools in this way.

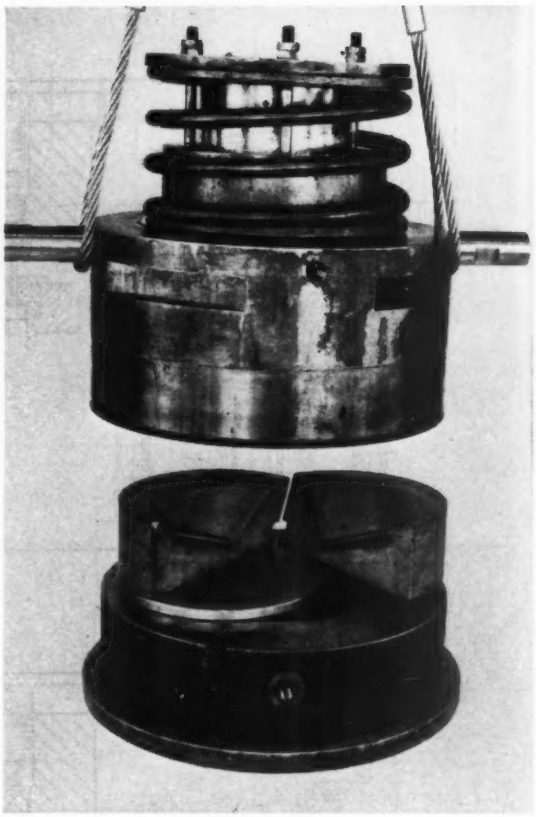


Fig. 10.

summary

The Fluid-Form attachment, which was installed at SAAB in 1953, has now been developed so that

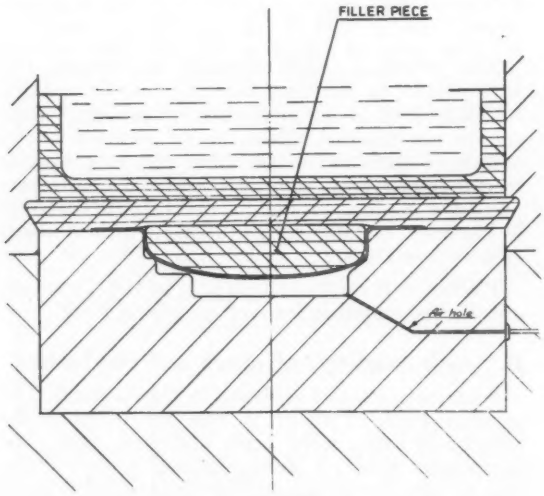


Fig. 11.

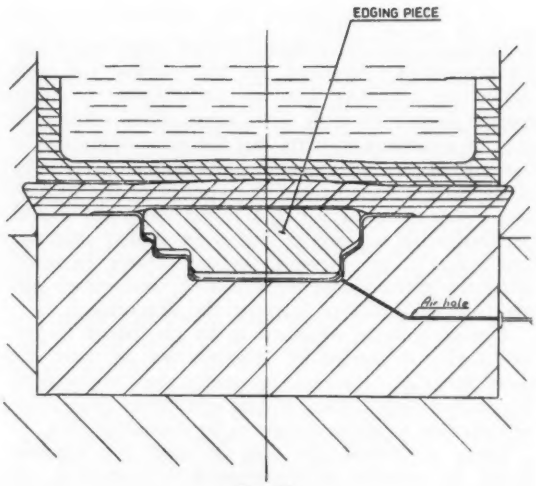


Fig. 12.

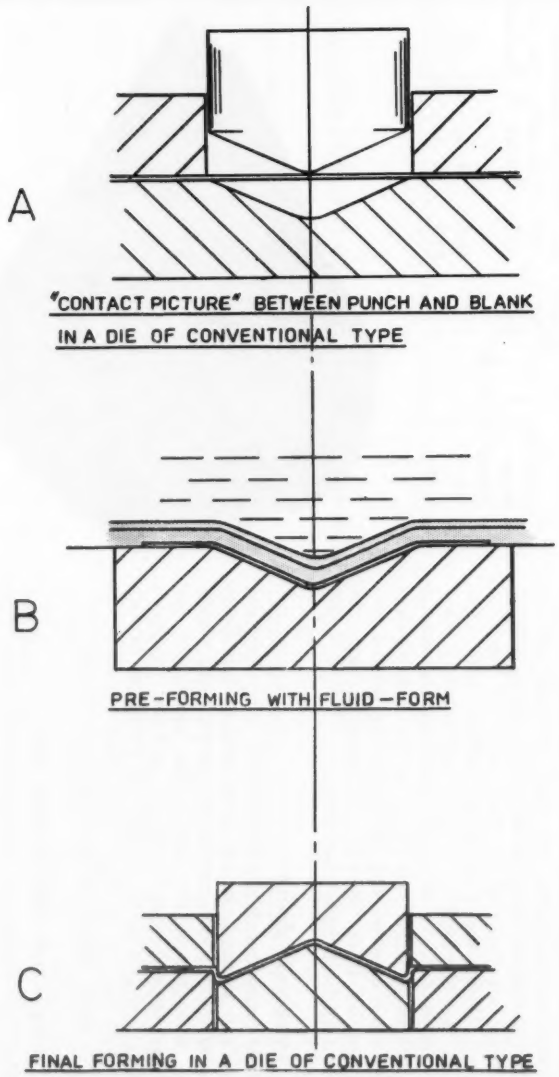


Fig. 13.

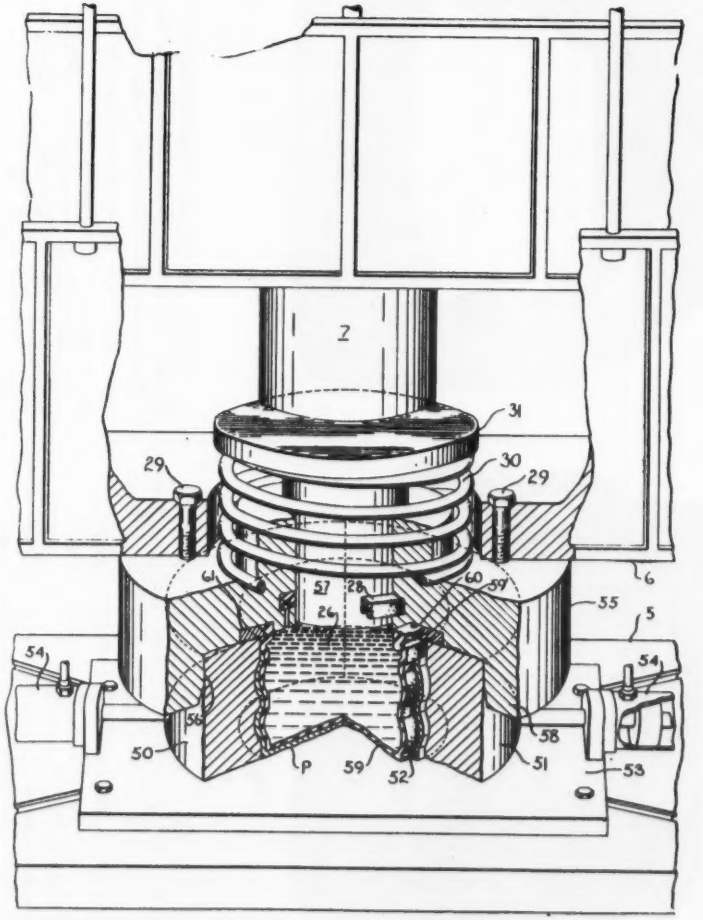


Fig. 16. Hydraulic forming attachment for presses.

Fig. 14.

Fig. 15.

the industry in general may derive benefit from it, and therefore the Fluid-Form is now introduced to a larger public. The advantages, which have been described earlier, can be summed up as follows :-

1. fewer operations

The flexible diaphragm gives a better "contact picture" than the rigid tool (see Figs. 2 and 3). Therefore, irregular shaped components, which are pressed by means of Fluid-Form in cavity tools, can generally be finish-formed in one operation without wrinkles. If the material stretch is so large that the forming cannot be done in one operation without intermediate annealing, the final forming can be carried out in the same tools, which almost without exception are made to the final shape of the component. When the Fluid-Form method with rigid punch and blankholder is used, and the steel blank is "wrapped" over the rigid punch by the flexible diaphragm, a larger reduction can be allowed than when using conventional methods owing to the perfect contact from the very beginning between the blank and the flexible diaphragm.

2. freedom in design

Since components with intricate and irregular shape can be made in one piece in the Fluid-Form attachment, the designer of the product can obtain more satisfying results, and at the same time the cost of production can be reduced, as fewer operations and more simple tools are required. Components with undercut can be made in split dies consisting of two or more pieces without extra operations.

3. more simple and cheaper tools

The Fluid-Form tools consist of fewer pieces than the conventional tools and are therefore cheaper to manufacture, especially as no careful fit between the upper and lower part is necessary, one of them being the flexible diaphragm. This flexible diaphragm also permits variations in the thickness of the blank.

For moderate production runs the tools can be made of plastics material and thus the machining can be completely eliminated.

In Table II are stated times and cost of material required for manufacturing a plastic tool for the component shown in Fig. 17.

TABLE II

	Labour hours	*Total elapsed time*	*Cost of material*	
Templates ...	5.5	5.5	1 :-kr	(1s. 6d.)
Wood model ...	10.2	10.2	4 :-kr	(5s. 6d.)
Manuf. of plastic tool	11.0	46.0	54 :-kr	(£3.16.0)
Total	26.7	61.7	59 :-kr	(£4. 3.6)

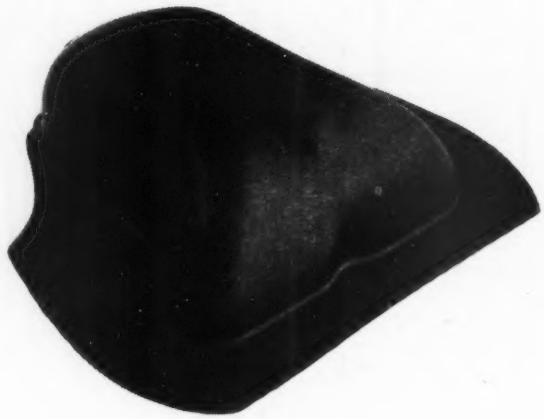


Fig. 17.

The total elapsed time is continuous and not dependent on the ordinary working-hours of the day. That is, if the tool drawing is available on Monday morning at 8 o'clock, the plastics tool will be ready for use in production after the number of hours shown in the column "Total elapsed time", calculated upon 24 hours a day, i.e., Wednesday evening at 9 o'clock, provided that the work is planned, so that the hardening procedures can be carried out after the ordinary working-hours.

4. shorter die-setting times

The die-setting time is almost eliminated owing to the simplicity of the tools. The tools are self-centring in the tool holder, no fixing is required and exchange can be carried out in the matter of 5 - 10 min.

5. higher quality

The flexible diaphragm gives an equal pressure over the whole sheet blank during the forming operation, and a better surface finish is obtained than in conventional tools. Springback in the part is usually completely eliminated.

6. special presses are not required

The Fluid-Form attachment can be fitted on all standard presses with sufficient presspower and shut height.

7. extensive use

The Fluid-Form attachment can be used for tools with cavity as well as for tools with rigid punch and blankholder. A prerequisite for the latter alternative is a press with hydro-pneumatic cushion having a capacity of approximately 10% of the press power.

The Fluid-Form attachment is primarily intended for manufacture in moderate production and for experimental purposes, but can also stand its ground on large production runs of components which are difficult to manufacture.

GRADUATE ADDITION TO TEACHERS' SALARIES

THE Ministry of Education has recently notified the Institution of the conditions now applicable to the above and as laid down by the Burnham Committee.

The Committee has decided that Associate Membership of The Institution of Production Engineers by examination should continue to be accepted for the purpose of the graduate addition, provided that the Associate Member has:

(a) fully satisfied the examination regulations for Associate Membership which have been in force since 1st September, 1959, either:

  (i) by passing the Associate Membership Examination after 1st September, 1959; or

  (ii) by passing an examination accepted by the Institution as giving exemption from the Associate Membership Examination held after 1st September, 1959; or

(b) passed the Associate Membership Examination not earlier than May, 1951, or an examination accepted after that date by the Institution as giving exemption from the Associate Membership Examination and

  (i) has passed at Advanced level the General Certificate of Education in Mathematics, or has an equivalent qualification; and

  (ii) has passed at Ordinary level the General Certificate of Education in Chemistry or Physics, or has an equivalent qualification.

PRECISION FORGING OF STEEL SHAFTS — concluded from page 324

electronic systems

On certain types of these machines introduced a few months ago, electronic systems of cycle control setting are incorporated to simplify procedure and to enable dimensional readings to be taken directly from drawings. It is possible in some cases also to profile forge through the medium of a manually-operated tracer head, copying directly from a drawing mounted on a special control desk adjacent to the machine. With the horizontal construction one can have work holding chucks to both right and left of the central forging box, each side being equipped with mechanical and automatic work loading and unloading devices. With such machines it is possible theoretically for production to continue without interruption throughout the working day.

To conclude, these methods of precision forging are foremost in the latest techniques of modern trends in manipulation of metals. They ensure the minimum of metal being consumed for manufacture of a given article, demanding the minimum of final processing by machining.

DEVELOPMENTS IN DIMENSIONAL ACCURACY

by K. J. HUME, B.Sc., M.I.Mech.E., M.I.Prod.E.

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Mr. Hume was educated at the Polytechnic School (now Quintin Grammar School) and later took a London degree at the Polytechnic. He trained as a hydrid physicist engineer at the National Physical Laboratory and entered production engineering in 1938, when he became Metrology Superintendent in The de Havilland Aircraft Company.

He has since held various other posts in industry and education and, in 1959, was appointed Reader in Engineering Production at Loughborough College of Technology, where he endeavours to pass on some of his experience to the rising generation of production engineers.

Mr. Hume has published a number of books, articles and papers, his best-known work being "Engineering Metrology", which is a standard textbook on the subject. He serves and has served on several Institution committees and is a Past Chairman of both the Papers and the Membership Committees. He is also active on B.S.I. committees in the field of metrology.

DIMENSIONAL accuracy in the production of goods and components can be reviewed from four aspects which are distinct and yet largely interdependent:

basic and reference standards;
specifications;
methods of measurement and inspection;
methods of production.

The most significant developments under the first heading naturally take place at the highest end of the accuracy scale since, in engineering, satisfactory working standards, such as slip gauges, have now become well-established to a sufficient accuracy for the majority of needs. Precision scales and line standards have been developed quite considerably during the last 10 or 15 years and have come back into the metrological limelight.

Specifications or "paper standards" play a very important part in improving accuracy. Sometimes they record the results of technical advancement and sometimes they are the incentive for such developments. Official specifications, such as British Standards, usually come into the first category, approaching the best existing practice but much higher than the worst. Thus they tend to bring about a general improvement, sometimes forcing lower quality products off the market.

Methods of measurement and inspection and methods of production are closely interlinked.

Improved inspection is of little value in itself unless it leads to improved or more economic production. In many cases production accuracy is improved, without physical improvements in machines or tooling, by a greater certainty of the accuracy of the product. A classical example of this is the application of statistical quality control, which does not even affect the physical processes of inspection.

The present Paper will deal mainly with the first two headings as there are certain marked developments in these fields which have, perhaps, received less attention than those concerned with the mechanics of production and inspection.

basic and reference standards

The present standard of length in the United Kingdom, the Imperial Standard Yard, has been in existence for over a century. This bronze bar which, despite all modern developments, is the only legal standard of length for English units in this country, was established in 1856. The standard immediately prior to that was legalised in 1824 but this was short-lived, as it was destroyed in the Houses of Parliament fire in 1834. Both these standards are line standards. That is, the 36 in. length is defined as the distance between two ruled lines on the bar.

Before 1834 the legal standard was a brass end bar established in the reign of Queen Elizabeth I. During the intervening period, however, there appear to have been various local standards, some of which can be seen in the Science Museum, London. Until quite recently the metric standard of length was a platinum iridium bar set up towards the end of the last century. There is good evidence that, while the metre bar has been remarkably stable, the lengths of the standard yard and its various copies have been consistently reducing. Dr. Barrell, of the National Physical Laboratory, in the 1957 Sir Alfred Herbert Paper, gives this shrinkage rate as about one millionth of an inch per year.

Over 130 years ago it was suggested that the wavelength of light might serve as a natural standard of length, and in 1893, A. A. Michelson and J. R. Benoit determined the length of the metre in terms of the red radiation of cadmium. Thus, a wavelength standard has been a practical proposition for nearly 70 years. In fact, evidence of the shrinkage of the Standard Yard and its copies has been obtained by comparison with wavelengths ever since that time. Various other wavelength determinations have since been made, in terms of both the yard and the metre, in this country, Germany, America, Japan and more recently in Russia. For some years, in fact, the chief standardising laboratories of the world have measured engineering end gauges directly in terms of wavelength.

The development of isotope production since the War brought an accurate wavelength standard much nearer realisation. In October, 1960, the International Bureau of Weights and Measures established a new definition of the metre. It is 1650763.73 wavelengths of the orange-red radiation of the Krypton 86 isotope.

Although this does not alter the legal position of the Imperial Standard Yard in this country, all scientific and technical measurements in English units have, for some years been based on this value with the conversion factor 25.4 mm to 1 in. exactly. This is known as the international inch and is accepted by the British Commonwealth and the United States, marking quite a step forward in international standardisation. No doubt the yard will eventually be legally redefined on this basis.

The practical engineer may perhaps scoff at the extreme accuracy which is constantly being aimed at by the scientists in standards laboratories. It is true, perhaps, that accuracies of a few parts in a hundred million or a thousand million may not have much direct effect on everyday work, but it is just as important that such developments must continually take place. In any field of activity it is a happy position when the standard of reference is one or two orders better than that needed at a particular time, although it is never long before scientific and technical needs begin to catch up with the standard.

The method used for wavelength measurement is interferometry and for the measurement of end standards a comparatively straightforward interferometer can be used. A particularly valuable feature is that any organisation, such as a private company or a technical institution, can set up its own absolute standard of length to an accuracy of one part in a million without having to carry material standards which must be referred periodically to the National Standardising laboratory.

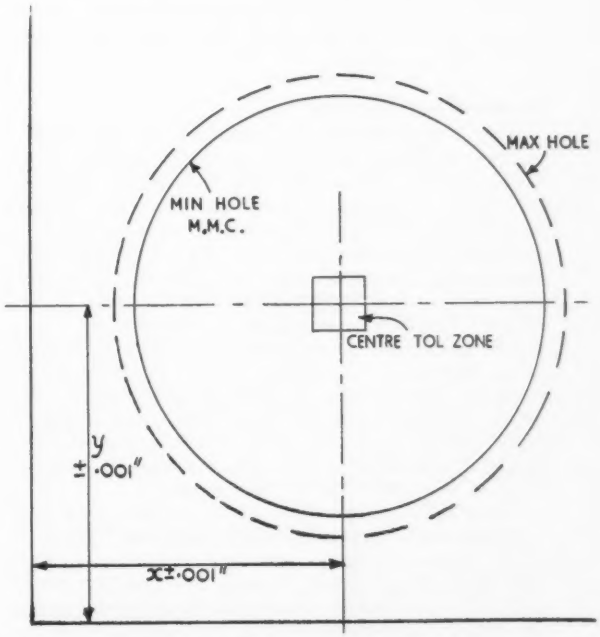


Fig. 1. Conventional Positional Tolerance. A positional tolerance defined by tolerances on co-ordinates gives a centre tolerance which varies with direction from ± 0.001 to ± 0.001 2.

"Shall we go over to the metric system?" This is a question which has been discussed periodically in this country over many many years. Up to a few years ago the answer from those concerned with engineering standardisation would be a very definite "No". For purely scientific work, of course, the metric system is universally used but in the British Commonwealth and U.S.A. the inch system, for all but a few engineering purposes, is so firmly entrenched that the cost and disorganisation of changing over might be quite unthinkable. It may well be, however, that international events will force even the United States into second thoughts about this problem. Where British and American engineering between them carried the greatest mass of engineering manufacture we could, to some extent, stick to our inches. But this balance is being upset and may well go the other way.

Russia is, of course, a metric country. India has recently gone right over to metric systems of weight, measures and finance. China, too, is or will be entirely metric. It is beginning to look as if even America, in sheer self-defence, may have to adopt the metric system as well. Such a change would take a long time to come fully into effect. Perhaps 100 years would not be too long to estimate. It might be thought that it would automatically make our arithmetic a lot easier but this is not necessarily so since, in engineering at any rate, decimalisation is the present rule. Except for large work where feet or yards may be used, the inch is no less convenient a unit than the millimetre. In a micrometer, for example, the one millimetre pitch screw and the divisions on the thimble are more awkward to read with an equivalent degree of accuracy than the inch micrometer with its 40 thread screw.

standard specifications

The British Standards Institution and its specifications are today household words. Its activities are not confined to the engineering industry, as was the case when it was founded early in this century as the Engineering Standards Committee. Since then it has extended into many other technological fields besides engineering, but it is only since the War that the man and woman in the street have become aware of the B.S.I. Kite mark and what it stands for.

The history of British Standards and the part they have played in the development of dimensional accuracy, particularly in engineering, is written in many specifications which have been issued, revised, and amended since the work was first started. We can be concerned here with only a few which indicate some of the landmarks in this progress.

Three of the most important recent developments in dimensional standards took place during 1952 and 1953. These standards were for Limits and Fits (B.S. 1916), Engineering Drawing Practice (B.S. 308), and two specifications relating to Gauge Tolerances, for Plain Limit Gauges (B.S. 969) and for Screw Gauges (B.S. 919).

The first specification for Limits and Fits was issued in 1906 as B.S. 164. The low number indicates its early origin in the history of British Standards. By comparison, new specifications issued during 1959 bore numbers over 3,000.

B.S. 164 was revised in 1924 and again in 1941. These early editions provided limits and fits for cylindrical and other simply dimensioned work but the specification never received much support from industry. It was in fact quite rare to find a company which admitted to using this specification in its design offices.

A few years after the War, the technical committee concerned was actively considering in what form a useful and acceptable standard for this important engineering function could be issued. In the words of the foreword to the standard itself: "Work on this revision had been completed and the new edition was approaching publication when developments occurred in the field of inter-services standardisation which made it appear desirable to review the whole question."

Around this time there was a great deal of international activity, particularly relating to the unified thread, and it was decided to base a new British Standard on the I.S.A. (International Federation of National Standardising Associations) system which was, of course, in metric units. A regular Services liaison had been built up between Britain, U.S.A. and Canada and this is now known as A.B.C.

Following the popular fashion of setting up new organisations with a fresh set of initials, the I.S.A. became the I.S.O. (International Organisation for Standardisation) and, while the I.S.A. had received support almost solely from European Continental countries, the I.S.O. embraces all the more advanced technological countries of the world.

Today, there seems to be much more co-operation and commonsense in the field of international standardisation than in international politics.

The I.S.A. system, which in this country has become B.S. 1916, provides 16 grades of tolerances and 21 types of fit for dimensions ranging from 0.04 in. to nearly 20 in. Committee work and experimental work has been in hand for some years to extend the range of sizes both above and below the present range. Almost any type of fit can be found and a second part of the specification gives recommendations for the types of fit which should be selected for different functional purposes, and a preferred selection of fits has been evolved.

As is generally known, systems of Limits and Fits can be either unilateral or bilateral and either on a hole or shaft basis. Whilst any one of these systems can be derived from the British Standard it is recommended that, wherever possible, a unilateral hole basis system should be employed.

This British Standard is compatible with previous specifications. Probably the earliest standard was the Newall system, and this is still widely used at the present time. It is, however, a bilateral system with very limited ranges and has proved quite inadequate for the wide variety of work required today. It is a pity, perhaps, that its more ardent adherents do not translate their existing drawings showing Newall tolerances to equivalent tolerances in B.S. 1916 or,

better still, revise their tolerances altogether to agree with the recommendations of the modern system.

There can be no doubt that this modern standard, although only a "paper specification", has contributed enormously to improvements in engineering accuracy, providing a universal system of standardisation and ensuring a much greater degree of interchangeability, even when mating components are manufactured in widely different places.

A British Standard for drawing office practice was first published in 1927 and revised in 1943. This standard B.S. 308, was again revised in 1953 and a great deal of the character of the specification was changed. The title was changed to "Engineering Drawing Practice" and much of the material in the earlier specification dealing with architectural and survey drawings, drawing reproduction and the handling of drawing materials has been excluded and is dealt with in other standards.

tolerancing of drawings

An important part of the new specification was the section dealing with the tolerancing of drawings. Valuable work done by an inter-services committee resulted in the publication, in 1948, of a booklet entitled "Dimensional Analysis of Engineering Designs". In this book, for the first time, were published ideas on dimensions and tolerances other than direct physical lengths and diameters. The concept of geometrical tolerances was introduced.

These tolerances were concerned with the accuracy of the relationship of one physical dimension to others and included separate tolerances on such things as roundness, straightness, symmetry, concentricity, position and so on. These principles have been incorporated in the drawing practice specification and, in particular, the engineer has come to recognise something new, the "maximum metal condition".

Although this idea was not completely new, it had not before received very much attention. It refers to the condition of any feature of a component such as a shaft or hole when the maximum amount of material is left on. It is of course, the maximum size of a shaft or the minimum size of a hole and it is always these limits which critically affect interchangeability.

In the past, the idea of a geometrical tolerance, straightness for example, was often glossed over when the dimensional tolerance was being considered. A designer might hold, for example, that the straightness of a shaft or accuracy of position of a mating hole and spigot had to be contained within the diameter tolerances he had specified. With the greater complexity of engineering components this had long ceased to be good enough and many weary arguments on such matters occurred, particularly during the War, between production, inspection and design office.

Where a geometrical or positional tolerance has been carefully worked out in relation to dimensional tolerances, it becomes obvious that in the majority

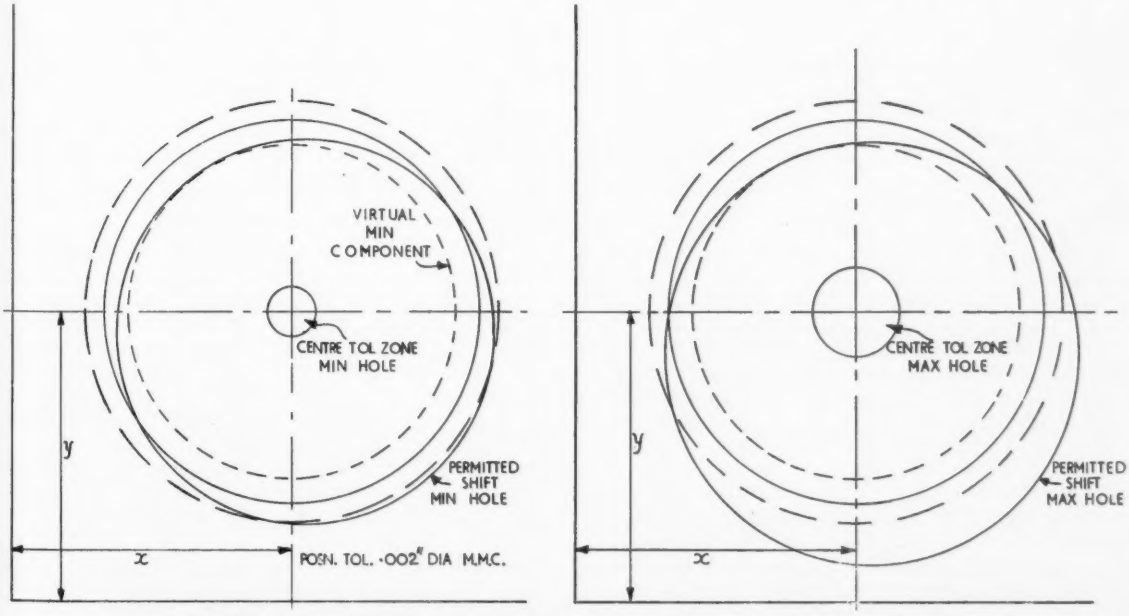


Fig. 2. Circular Zone Positional Tolerance. The positional tolerance is uniform in all directions. By associating this tolerance with the "maximum metal condition", the zone is enlarged automatically by any amount by which the hole is above its low limit. This condition can normally be allowed and is ensured by a fixed gauging location plug equal in diameter to the virtual low component. The accuracy of hole diameter within its limits must be gauged separately from position.

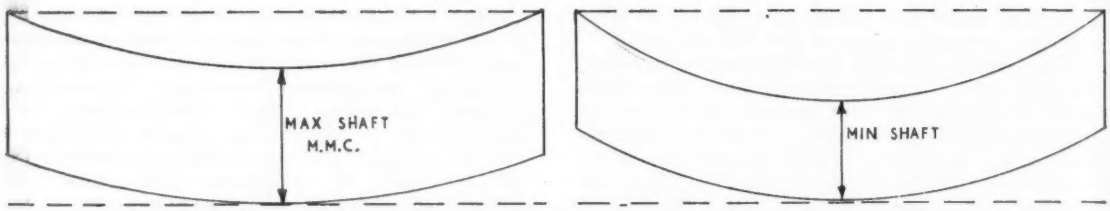


Fig. 3. Tolerance on Straightness. As in the case of positional tolerances, tolerance on straightness, parallelism, etc., may be increased for a component not on its maximum metal condition.

of cases greater positional errors can be allowed where the clearance between mating parts is wide than when the fit is close. In other words, minimum geometrical tolerances can be related to the maximum metal condition of components. These positional tolerances may be increased where the actual dimensions of components lie somewhere between the maximum and minimum metal limits.

Again, the general effect of all these new conceptions has led to improvements in accuracy even if the total tolerances may appear larger on paper. The improvement in accuracy comes about, as in so many other cases, by the certainty which is introduced in manufacture. If every one on the production line, from the man on the shop floor to the chief production engineer, knows exactly what is required, with nothing left to guesswork or inspired intuition, the components coming off the line are bound to be more consistent and generally of a higher accuracy.

Specifications for limits and tolerances for screw gauges and plain limit gauges were first published in 1940 and 1941 respectively. Prior to that, there had been tolerances for screw gauges drawn up by the N.P.L. many years previously. There was no accepted specification for tolerances on limit gauges although there was fortunately an almost universal agreement that gauge tolerances should be 10% of the work tolerance. These tolerances were also based on the workshop and inspection principle which had been established during the First World War.

In 1952, revisions of most of these specifications introduced a new principle into limit gauging for both screw threads and plain work. The old principle of workshop and inspection gauges was abandoned and a new "general" gauge was introduced. It is well-known that the workshop gauge tolerance allowed a gauge to encroach on the work tolerance by 10% at each end, while the inspection gauge tolerance permitted the work tolerance to be in effect extended 10% at each end. This is not to say that every gauge had this extreme effect but, in theory, it was possible for a set of gauges to do so. This system arose from the principle established in the early part of the First World War when Government departments were about the only people to inspect articles in bulk, mainly munitions.

If the manufacturer used workshop gauges and his customer used inspection gauges — and both used correct gauges and used them correctly — it was certain that any work passed by the workshop gauge would automatically pass the inspection gauge.

A theoretical drawback to this system which, it must be admitted, was more apparent than real, was that components which had to assemble with very little clearance could pass their respective inspection gauges and yet refuse to assemble. Advances in component accuracy and the reduction of assembly clearances in many fields have made it essential that components should be strictly within the limits laid down by the designer. Theoretically, the problem is insoluble.

Unless every gauge is perfect, it must either encroach on the work tolerance or pass work which is outside the tolerance. After a great deal of investigation, discussion and argument it was finally agreed to compromise and the "general" gauge was born. Broadly speaking it has a workshop "go" and an inspection "not go". This means that component dimensions are kept strictly within their tolerance at the "go" or maximum metal end but may be slightly outside tolerance at the "not go" or minimum metal end. Thus interchangeability is assured and the possible 10% increase at the other end of the tolerance is of little consequence in most cases.

high precision measuring equipment

There is a range of instruments such as precision comparators, measuring machines, optical dividing heads and tables, thread measuring machines and so on which do not come within British Standards. Some of this equipment, particularly thread measuring machines, was designed by the National Physical Laboratory during or shortly after the First World War. It was a condition of the licence to manufacture that any such equipment made for sale had to be sent to the Laboratory for certification before issue. During the years between the Wars a good deal of precision optical equipment was developed. Initially, this was of Continental origin but, with the urgent needs of war, British manufacturers filled the gap when Continental equipment could no longer be obtained. Today, the best British equipment is as good as the best Continental equipment.

Quite naturally, many of these instruments also were sent for certification by the National Physical Laboratory but since manufacturers already had to have facilities for checking their instruments, a system was eventually adopted whereby each company issued

its own certificate to a specification agreed by the N.P.L. There is, of course, still no objection to any purchaser requesting an N.P.L. certificate with an instrument. The specifications now used for certifying instruments are those previously drawn up by the N.P.L. for its own use in testing them. Certain of these specifications, for end bars and sine bars for example, have formed the basis of British standards and, just before the War, similar standards based on N.P.L. test schedules were issued for very widely used equipment such as micrometers and slip gauges.

methods of measurement and inspection

Methods of measurement and inspection have developed so widely over the last 20 years or so that it would be very difficult to treat them in any detail in a survey such as this. Some developments in the highest precision measurement have already been mentioned and we have seen that the foundations were laid even before the beginning of the century. In a similar way the foundation of high precision in ordinary production inspection was laid in the 1920's and of course, received considerable impetus during the Second World War. By the end of the War measuring instruments and inspection technique had, to a large extent, been established. Since then, developments have taken place more in detailed refinement and improvements in technique although there have still been several revolutionary changes.

Two of the most important of these have been the development of automatic inspection methods and the gradual introduction of statistical quality control. Automatic inspection has stemmed from the days when a few companies, both in this country and the U.S.A., introduced the principles of limit gauge indicators. Initially these consisted of limit indicator units which could be adjusted to various component tolerances and would indicate by green, amber and red lights whether a component was within, above or below its limits.

From these instruments were developed multi-dimensional machines in which a number of such units were combined to gauge simultaneously various dimensions of a complex component. It was not long before the electrical signals, which had merely operated lights, were used to operate relays and mechanically control the selection of components. Thus the high speed sorting machine was introduced. This automatically grades into several size ranges such items as needle bearings, balls, rollers and similar simple components. Multi-dimensional gauging machines were then applied to the segregation of faults. Components are deflected into containers, each

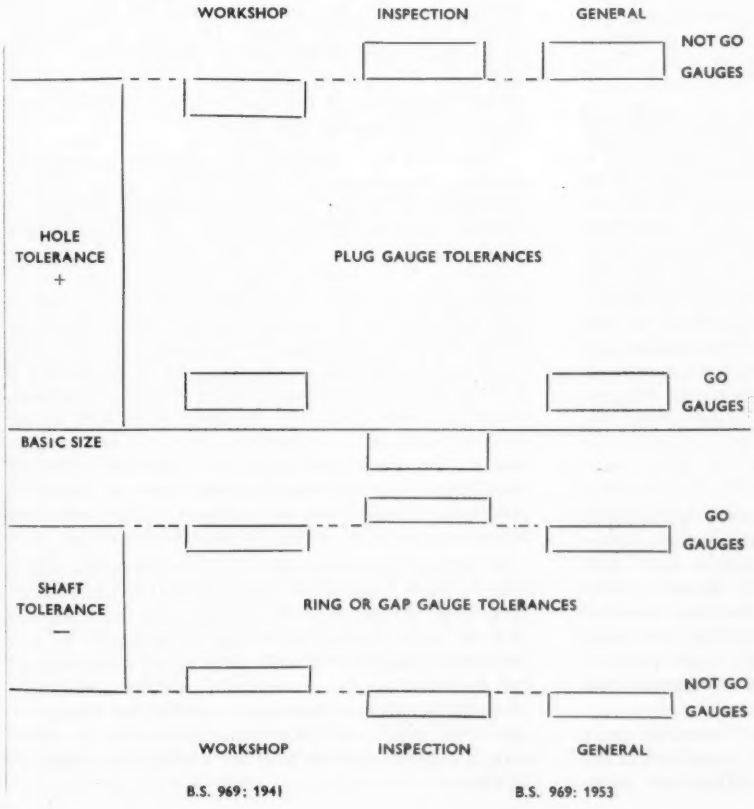


Fig. 4. Limit Gauge Tolerances. In BS 969 : 1941, the workshop gauge could encroach on the work tolerance, but the inspection gauge could lie outside it and prejudice interchangeability. The general gauge can encroach on work tolerance at the maximum metal condition only, and only at the mimimum metal condition will the Not Go gauge allow work to exceed its tolerance. Interchangeability is thus ensured and the possible slight increase in work tolerance is usually unimportant.

of which represents a fault on a particular dimension or, of course, fully correct.

It is sometimes argued, generally by those who are wholly concerned with production and not inspection methods, that inspection itself can never improve the accuracy or quality of an article. This is partly true, for once an article is made no amount of inspection can rectify the faults in it. Bearing this in mind, it is quite surprising how often the inspector or inspection department gets the blame for the quantity of scrap produced! Nevertheless, there is nothing like knowing what the faults are and where they lie to assist in improving the product. The finest production machines ever made could not produce accurate work unless there were also available accurate methods for setting the machines and checking their products.

Automatic gauging is now applied to the component while it is still being manufactured. The signals from the gauging device control the machine to keep the dimensions within their limits. It is the same principle which is being so widely developed today in tape controlled machining. The conventional production-inspection procedure of reporting and correction has been replaced by an automatic closed control loop within the manufacturing equipment itself. Undoubtedly this process will be greatly accelerated in future years.

Another development which has had a tremendous effect on accuracy of produced components is statistical quality control. It is perhaps surprising that this technique, which is not even directly concerned with the physical processes of checking, should have had such a marked influence. It is merely the application of statistical mathematics to the system of inspection. Engineers have long recognised, although perhaps few will admit it, that 100% inspection is by no means infallible, particularly when applied to repetition measurement of a large number of components. It can be proved that, if proper sampling systems are introduced, the risk of defects getting through is no greater, or can even be smaller, than the 100% inspection. The most valuable feature of S.Q.C. is in its application directly on the shop floor. In this way it enables inspection control to be carried out in real time and not after work has been scrapped. By using statistical laws, future defects can be predicted and avoiding action taken before they can happen.

methods of production

Improvements and developments in production methods have taken place in the past few years over such a wide range that it is difficult to select any which are more important than others. Improvements in accuracy are not by any means confined to components and dimensions of the highest precision. Significant developments have taken place particularly in the field of casting and forming metals and other substances.

The techniques of die-casting have for many years been accepted as capable of giving great improvements in accuracy and economics. More and more components are being produced in the finished or near finished condition which, prior to the adoption of die-casting, would have had a good deal of machining work done on them. In the past perhaps the die-casting has been looked upon as something inferior to the heavier and perhaps more robust machined article. Provided the design is right and the suitability of a die-casting properly assessed, there is no reason why it should not be better than its predecessor both functionally as well as economically.

Shell moulding has introduced quite a new precision into the comparatively inaccurate process of sand casting. The increased accuracy obtained in this initial stage can be reflected right through to the final product and often provides greater savings than other refinements further along the production line. The same can be said for investment casting, where dimensions of quite high precision can be obtained without the need for further processing.

wasteful processes

The production engineer today is becoming more and more aware of the wasteful nature of many of the traditional production processes. The Chief Production Engineer of one of our major motor manufacturers recently estimated that his group alone wasted some £20,000,000 a year in cutting metal for scrap. This did not take into account the costs of the cutting processes, but was merely the difference between the high price paid for metal as castings or forgings and the low price received for scrap metal which had been cut away. The cost of material, particularly some of the special and expensive alloys and other compounds used today, represents a much higher proportion of the total cost of an article than it did, say, before the last War.

Digressing for a moment it is salutary to stop and consider that material of itself has no value. What is raw material to one firm is the finished product of another and into it has gone the cost of labour and overheads in getting it to the state at which it is passed on. This goes on right down the line to the point where the really raw material is mined or otherwise obtained from natural sources. Apart from the profit (and this point may be debatable) all the value attaching to material at any stage of its processing is due to the cost of labour, either direct or indirect, which has been used on it. Indirect costs, such as the costs of machines, is sometimes quite a large proportion of the whole but again the monetary value of these items can be traced to the cost of labour in producing them. Costs of transport, office work and all other so-called overheads must be included.

It follows, therefore, that any developments which lead to more forming of material, rather than scrapping large proportions of it, must give economic as well as, quite often, functional advantages. A very important example of such functional improvement can be found in the processes of powder metallurgy. Not only is this economical of material but things are produced which could be manufactured in no other way. Tungsten carbide tools are an excellent example of this.

improved accuracy

In the world of machining, accuracy is continually being improved by the development of the machine tools themselves. Developments in grinding techniques and improvements in both journal and rolling bearings have contributed to accuracy in production. Here, the improved accuracy owes a lot to refined methods of inspection. It is now possible to measure the roundness of components to within a few millionths of an inch and this fact alone has helped the improvements mentioned in bearings. Along with this has gone the realisation that cleanliness in assembly is essential if the improved dimensional accuracy of component parts is to be fully exploited.

automatic control

Another great contribution to dimensional accuracy has been automatic control of machine tools. While in some cases the machines themselves are not inherently more accurate, the application of automatic control has made their operation more certain, simpler and more consistent as well as being more economical. Automatic control of contour milling, for example, produces a smoother cutting action, greater certainty of dimension and again improved economy. Automatic positioning on jig borers and similar types of machine can lead to greater accuracy. Once the tape or punched card have been produced they can be checked and re-checked if necessary before the job goes on the machine.

In another type of semi-automatic jig borer, the first component is produced by conventional methods of setting but each setting can be recorded in a store and reproduced as many times as required on subsequent components. Each of these systems has its place and there will undoubtedly be many further developments in this type of work.

Although automatic positioning has now been satisfactorily achieved, automatic variation of size of hole still lies in the future. Even now, machines are made which will select appropriate sizes from a magazine of tools which have been pre-set for cutting a given dimension, but there may still be a field of development for the automatically controlled boring head which will feed back the size of the hole it is cutting in the same way as the table position is now fed back and controls the accuracy of positioning.

striking advances

There are two striking developments which are probably more important to machine tool development than anything else since tape control was introduced. The first, Moiré fringe techniques, were first used on tape controlled machines but it is the further developments and applications of these techniques which have gone even further than this. The second, air and oil film bearings, are also complementary to automatic machine control.

A most interesting and important application of Moiré fringes was shown at the Machine Tool Exhibition in 1960. From the earlier straight diffraction gratings, development has led to radial gratings which will do for circular measure what the straight gratings did for linear measurement. Two such gratings, attached to two components of a machine, such as the worm and worm wheel of a gear hobber, enable the relative movements to be corrected instantaneously for any mechanical errors such as pitch or division. The number of rulings on each grating is in proportion to the velocity ratio and the sinusoidal signals from each will remain in a constant phase relationship only if the mechanical transmission is, at every instant, the same as the angular relationship of the gratings. Any phase difference can be arranged to produce an amplified signal which will operate a servo system driving a differential gear which applies an appropriate mechanical correction. Since the gratings can be produced with a higher overall accuracy than mechanical components in most cases, the accuracy of the machine can also be increased without the difficulties and expense of mechanically correcting screws and gearing to a very high order.

In air and oil film bearings, the air or oil is forced under pressure between the bearing surfaces which therefore never touch one another. Friction is reduced enormously and, in addition, there is a tendency for the film to even out the effects of any small irregularities in the surfaces. One of the greatest problems in automatic control of machine tools has been the power required to move slideways, simple enough with ordinary motors but very difficult and expensive with servo-motors.

As so often happens, these developments have come at just the right time when they were needed for technical progress.

conclusions and future developments

With the establishment of an atomic standard of length (and, incidentally, of time), it is difficult to see how the ultimate accuracy can be substantially improved. It is, however, probable that centimetric radar methods will give even higher accuracy than a few parts in 10^9 for large scale measurement used in surveying. We may yet see a more accurate standard mile than standard yard.

The progress of production methods, improved tooling and refinements in measuring techniques will all continue to develop dimensional accuracy. As we have seen, this is inevitably reflected in the standards of accuracy laid down in specifications. Developments will not be confined to the highest levels. Economically there is much more to be gained by improvements lower down the scale.

Although this Paper has been confined to dimensional engineering, much of our technological progress today depends on developments in other physical, chemical and metallurgical directions such as the purity and electrical properties of various materials.

In all these fields, with the increase of knowledge, the artificial barriers between physics, chemistry and engineering become less distinct and we have the apparent paradox of demanding more and more specialisation at the same time as we need to take a wider view of the whole of science.

THE EFFECTIVE DIAMETER OF A PARALLEL SCREW THREAD

by L. W. NICKOLS, B.Sc.(Eng.), M.I.Mech.E., M.I.Prod.E.

A communication from the National Physical Laboratory

Synopsis

Two different interpretations of the effective diameter are in use in various countries, mainly as a result of differing techniques of measurement, and the difference between these interpretations is discussed. The importance of pitch errors in relation to their effect on the fit of mating threads is described, together with the concept of the virtual effective diameter as a means of establishing systems of limits and tolerances for screw threads.

The requirements for assembly of screws and nuts are given and the calculation of the virtual effective diameters of screw threads is discussed in relation to the different interpretations of the effective diameter.

Finally, the relation between the two interpretations and the associated measuring techniques is discussed. It is shown that the common definition of effective diameter adopted by the United Kingdom and the U.S.A. is that best suited to their gauging and measuring techniques.

1. introduction

Of the elements which define a screw thread, the effective diameter is the most important, because the manufacturing limits of size specified for the effective diameters of mating threads determine the clearance between the flanks of the threads and also the maximum pitch and flank angle errors that may be permitted; the clearance between the flanks and the pitch errors both affect the stripping strength of the screwed assembly. In view of its importance it is unfortunate that many people find difficulty in fully understanding the concept of the effective diameter; this difficulty is not made less by the existence of two different interpretations of the effective diameter, as will be seen below, which have arisen mainly as a result of differing techniques of measurement.

2. definition of effective diameter

One definition which used to be current in the United Kingdom, and which is still commonly accepted on the Continent, is given below. It is termed definition "A" in the discussion which follows.

"*The effective diameter is the diameter of an imaginary cylinder, coaxial with the thread, which intersects the surface of the thread in such a manner that the intercepts formed by the thread groove and ridge on a generator of the cylinder are equal.*"

In practice, screw threads generally have pitch errors, and, for this reason, it has been found advisable in the United Kingdom and the U.S.A. to accept a modified definition, termed definition "B", given below.

"*The effective diameter is the diameter of an imaginary cylinder, coaxial with the thread, which intersects the surface of the thread in such a manner*

that the intercept formed by a thread groove on a generator of the cylinder is equal to one-half the basic pitch". *

If a screw thread has no pitch error then the effective diameters "A" and "B" defined in the above two ways are identical in size. If, however, the screw thread has a pitch error, then the effective diameters will differ in size. This difference in size is shown in Fig. 1 for the two cases of a screw having pitch errors of magnitude + δp and – δp respectively *per turn of thread.* The difference between the lengths of the intercepts referred to in definitions "A" and "B" above is 0.5 δp.

It will be noted that effective diameter "A" is larger than effective diameter "B" when the pitch error is + ve, and smaller when the pitch error is – ve, but in both cases the difference in size "Y" between these effective diameters is given by the equation :

$$Y = 0.5\ \delta p.\ \cot \alpha \qquad \ldots\ldots(1)$$

in which α is the flank angle of the screw.

Consider an assembled screw and nut in which the thread forms are in contact with each other over the complete length of engagement. Then it is reasonable to assume that the effective diameters of the screw and nut are of the same size. If the threads have no pitch errors then this assumption is correct whether the effective diameter is defined according to definition "A" or "B" respectively. If, however, the mating threads have identical pitch errors (in magnitude and sign), then the thread forms will still be in contact with each other over the complete length of engagement, but the above assumption will only hold if the effective diameter is defined according to definition "A". For example, Fig. 2 shows two possible cases, for a + ve pitch error and a – ve pitch error respectively, of a screw and nut which fit exactly. By definition "A" the effective diameter of the screw is the same as that of its mating nut in both cases. By definition "B" the effective diameter of the screw differs from that of its mating nut in both cases, being smaller for a + ve pitch error and larger for a – ve pitch error. Based on this consideration, definition "A" would appear to be preferable,

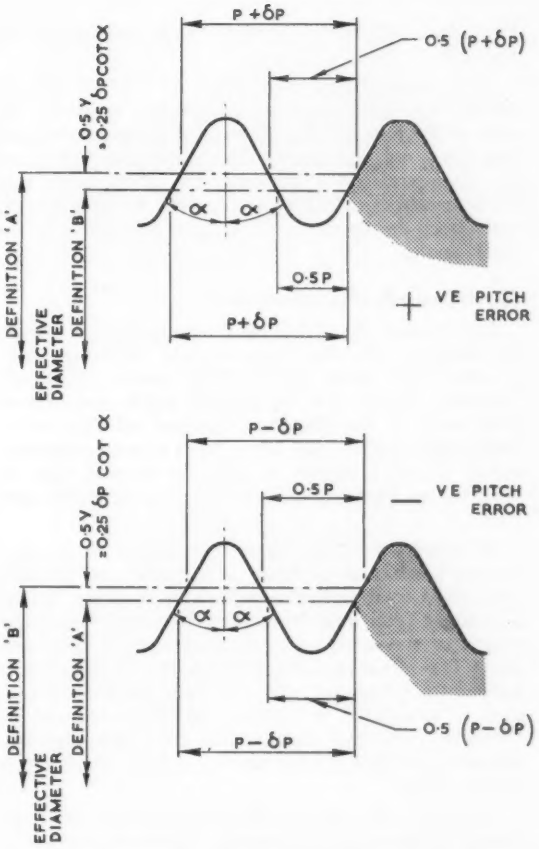
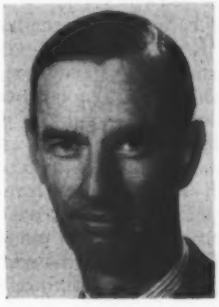


FIG. 1. DEFINITIONS OF EFFECTIVE DIAMETER
p = basic pitch δp = pitch error over one turn of thread

but now assume that the effective diameters, defined according to definition "A", of the screws and nuts in Fig. 2(a) and Fig. 2(b) are of the same size. Although the effective diameter of the screw in Fig. 2(a) is the same as that of the nut in Fig. 2(b) the two will not assemble, because of the difference between their pitch errors. Similarly the nut in

* This definition corresponds to that given in B.S. 2517 : 1954, "Definitions for use in Mechanical Engineering".



Mr. Nickols was educated at the City of London School and King's College, University of London, from which he graduated with First Class Honours in 1933.

After serving an apprenticeship with the Wellman-Smith-Owen Engineering Corporation, Darlaston, S. Staffs, he joined Stewarts & Lloyds, Ltd., Corby, in 1936. In 1938 he left to take up a position on the staff of the Metrology (later Standards) Division of the National Physical Laboratory, where he is now a Senior Principal Scientific Officer in charge of the engineering group. In 1951 he was seconded for a year to the U.K. Scientific Mission, Washington, D.C., where he was Mechanical Engineering Liaison Officer.

Mr. Nickols has taken an active part in engineering standardisation, particularly in connection with screw threads and limits and fits, and he is Chairman of the Metrology Working Group of the ISO Limits and Fits Committee.

Fig. 2(a) will not assemble with the screw in Fig. 2(b).

Using either definitions "A" or "B" it will be noted, therefore, that the difference between the sizes of the effective diameters of a mating screw and nut does not necessarily determine the degree of fit (diametral play) between the screw and nut. Relative errors of pitch between the mating threads will affect the degree of fit, as also will errors in the flank angles.

3. virtual effective diameter

It is evident that if the effective diameter is defined by either of the two ways already described, then a screw with pitch and/or flank angle errors will assemble with a nut of perfect pitch and thread form only if the effective diameter of this nut is larger than that of the screw by a certain minimum value. This, of course, is with the proviso that no interference occurs between the mating crests and roots.

In other words, the effective diameter of a screw having pitch and/or flank angle errors is virtually equivalent to the effective diameter of a nut thread of perfect pitch and form with which the complete length of the screw will assemble *with no diametral play*. The effective diameter of such a nut thread is termed the "virtual" effective diameter of the screw, and is calculated by *adding* to the measured or "simple" effective diameter of the screw the diametral equivalents of the pitch and flank angle errors of the screw.

Similarly, the virtual effective diameter of a nut thread is the effective diameter of a screw of perfect pitch and form with which the nut will assemble with no diametral play. The virtual effective diameter of a nut thread is calculated by *subtracting* the diametral equivalents of its pitch and flank angle errors from its measured "simple" effective diameter.

It should be emphasised at this stage that, as in the case of the simple effective diameters, the difference between the sizes of the virtual effective diameters of a mating screw and nut does not necessarily determine the degree of fit (diametral play) between the screw and nut. For example, the diametral play between the flanks of a mating screw and nut which have identical pitch errors and identical flank angle errors, both in magnitude and sign, will be equal to the difference in size between their *simple* effective diameters defined according to definition "A". Only in the special case when the pitch and flank angle errors are of equal magnitude but of opposite sign will the diametral play be equal to the difference in size between the two virtual effective diameters.

The diametral play between the flanks of two mating threads depends upon their relative pitch and flank angle errors, and will lie between two limits, the maximum limit being the difference in size of the two simple effective diameters "A" and the minimum limit being the difference in size of the two virtual effective diameters. It is assumed, of course, that no interference occurs between the crests of one thread and the roots of the mating thread.

4. requirements for assembly of screws and nuts

It follows as a corollary of the above that in order to guarantee complete assembly of screws and nuts made to any one nominal size, and which may have + ve and − ve errors of pitch and flank angles, the

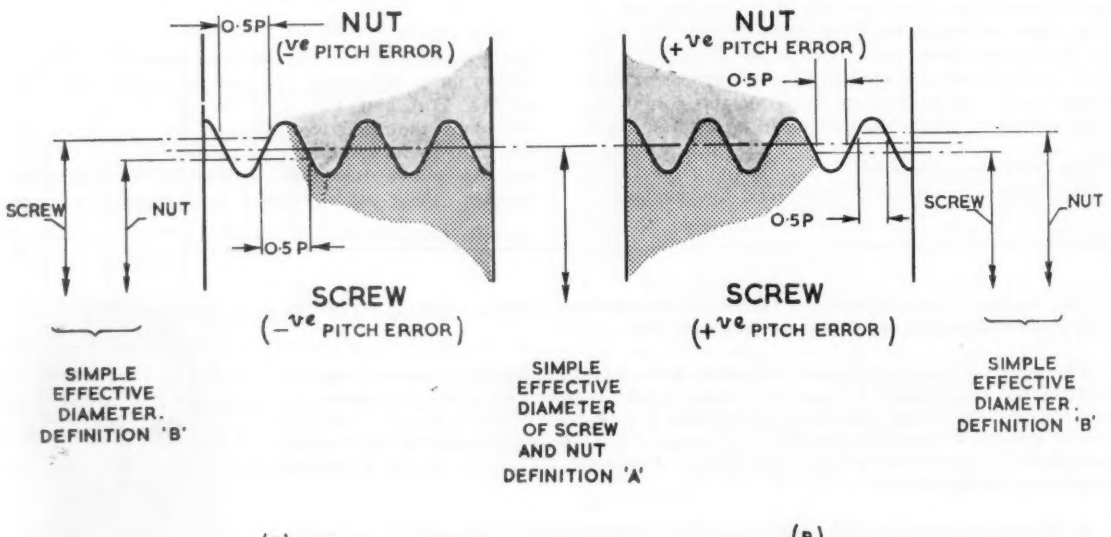


Fig. 2

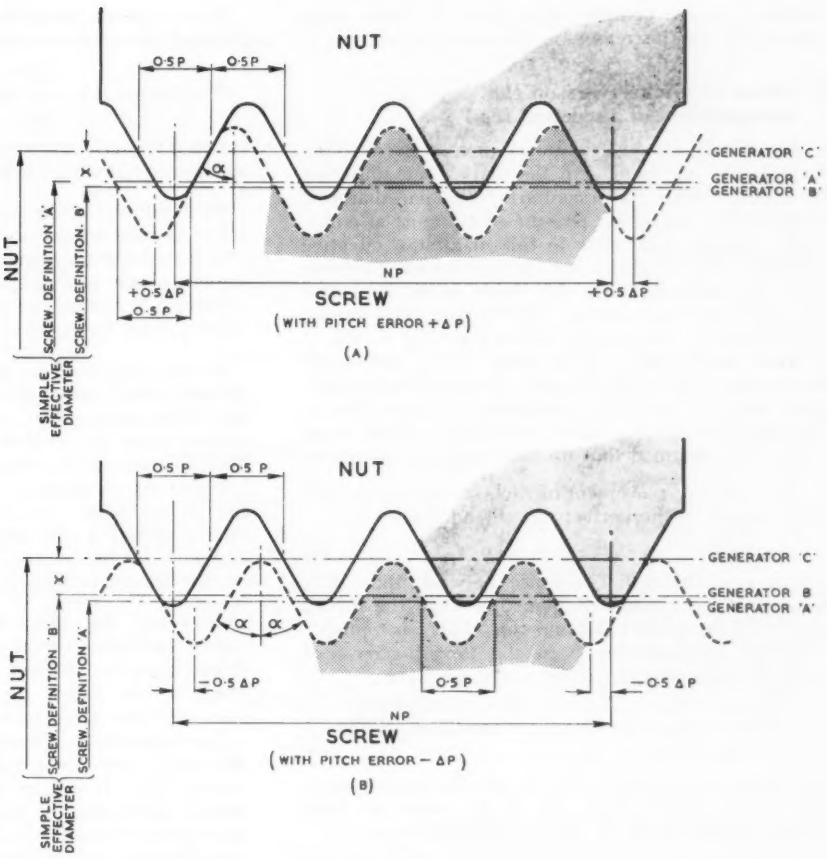


Fig. 3

virtual effective diameters of the screws over the length of engagement with the nuts must not be greater than the virtual effective diameters of the nuts. This requirement is a fundamental basis of any system of limits and tolerances for the effective diameters of mating screw threads which are required to assemble without interference. In such a system of limits and tolerances, maximum and minimum limits of size are specified for the effective diameters of the screws and nuts.

For the flanks of the mating threads to assemble without interference and with diametral play not greater than the maximum permissible, we have the following requirements:

(a) the maximum limit specified for the screw effective diameter must not be greater than the minimum limit specified for the nut effective diameter;

(b) the simple effective diameter of the screw must lie on or above the minimum limit specified for the screw effective diameter, and the simple effective diameter of the nut must lie on or below the maximum limit specified for the nut effective diameter;

(c) the virtual effective diameter of the screw over the length of engagement with the nut must not be greater than the maximum limit specified for the screw effective diameter, and the virtual effective diameter of the nut must not be less than the minimum limit specified for the nut effective diameter.

In practice, it may also be desirable to specify a minimum clearance or "allowance" between the maximum specified effective diameter of the screw and the minimum specified effective diameter of the nut.

It will be noted from (b) and (c) above that the tolerance on the effective diameter is intended to include not only the errors of the simple effective diameter, but also the diametral equivalent of the pitch and flank angle errors. It is not proposed to deal here with the method of calculating the diametral equivalent of the flank angle errors of a screw or nut, because this method is well-known.[1] Also, for any one screw thread, the diametral equivalent of the flank angle errors is not affected to a significant extent in practice by the difference in size of effective diameters "A" and "B" mentioned earlier. The effect of pitch errors on the acceptability of a screw

thread is more complex than that of flank angle errors and, for this reason, is discussed below.

5. effect of pitch errors on the acceptability of a screw thread

The virtual effective diameter of a screw over the length of engagement with the mating nut must not be greater than the maximum effective diameter specified for the screw, i.e., the screw must assemble with a perfect nut made to this maximum effective diameter. Fig. 3 shows two screws which assemble with this perfect nut so that there is no diametral play between each screw and the nut. The thread represented by the dotted line in Fig. 3(a) is that of a screw which has a pitch error $+\triangle p$, measured to the centre of the groove, over the length of engagement with the nut; the corresponding dotted line in Fig. 3(b) represents a screw which has a pitch error $-\triangle p$. It is assumed that no flank angle errors occur.

The *radial* displacement of each screw thread form with respect to the perfect nut thread form is :

$$x = 0.5\ \triangle p.\ \cot \alpha \qquad \ldots\ldots(2)$$

where x is the radial distance between the "half basic pitch" intercept on generator C in the thread groove of the perfect nut and the "half basic pitch" intercept on generator B in the thread groove of each of the screws. In other words we have :

Virtual effective diameter of screw = simple effective diameter of screw (definition "B") $+\triangle p.\ \cot \alpha$ .....(3)

The factor $\triangle p.\ \cot \alpha$, which is the diametral equivalent of the pitch error $\triangle p$, is the same for both screws, regardless of the sign of the pitch error.

In Fig. 3, generator A represents the generator of the imaginary cylinder, coaxial with the thread, which intersects the surface of the screw in such a manner that the intercepts formed by the thread groove and ridge are equal. Generator A is, therefore, the line to which the effective diameter "A" is measured. The correction to the simple effective diameter (definition "A") of each screw to obtain the virtual effective diameter is represented by twice the distance between the generators A and C. It will be seen from Fig. 3 that this correction would not be the same for a + ve pitch error as for a − ve pitch error.

For a pitch error $+\triangle p$ we have :

Virtual effective diameter of screw = simple effective diameter of screw (definition "A")

$$+\triangle p \cot \alpha - 0.5 \frac{\triangle p}{n} \cot \alpha \qquad \ldots\ldots(4)$$

for a pitch error $-\triangle p$ we have :

Virtual effective diameter of screw = simple effective diameter of screw (definition "A")

$$+\triangle p \cot \alpha + 0.5 \frac{\triangle p}{n} \cot \alpha \qquad \ldots\ldots(5)$$

Note : n in the foregoing equations is the number of turns of thread in the length of engagement.

The factor $0.5 \frac{\triangle p}{n}. \cot \alpha$ is the difference in size between the effective diameters "A" and "B" and has been dealt with earlier (Equation (1)).

If, in addition to the pitch errors, flank angle errors occur on the screws, then it would be necessary to add the diametral equivalent of these flank angle errors to the right-hand sides of the latter three equations in order to obtain the virtual effective diameters of the screws.

So far, consideration has been given only to screw threads which, although they might have pitch errors and flank angle errors, are uniform in diameter. In certain cases the method of manufacture may produce threads which, although nominally parallel, are not uniform in diameter but taper slightly from one end to the other. The virtual effective diameter of such a thread is still defined by the simple effective diameter of the perfect mating thread which just fits the thread in question.

However, the effect of errors of pitch on the virtual effective diameter of the slightly tapered thread may be masked partially or wholly by the effect of the taper. Fig. 4 shows slightly tapered screws of this kind, having pitch errors $+\triangle p$ and $-\triangle p$ respectively, measured parallel to the axis of the screw, over the lengths of engagement with the mating nuts. It will be seen that providing the diametral taper over the length of engagement is equal to or greater than $2\ \triangle p.\ \cot \alpha$ then the pitch errors do not affect the virtual effective diameter, which is now equal to the sum of the maximum simple effective diameter of the screw and the diametral equivalent of the flank angle errors.

If, however, the diametral taper over the length of engagement is less than $2\ \triangle p.\ \cot \alpha$ it can be shown that :

Virtual effective diameter of screw = simple effective diameter of screw (definition "B") $+\triangle p \cot \alpha - \frac{1}{2}$ diametral taper over length of engagement + diametral equivalent of flank angle errors .....(6)

If the simple effective diameter of the screw has been measured in accordance with definition "A" then it will be necessary to add or subtract an additional factor $0.5 \frac{\triangle p}{n}. \cot \alpha$ to or from the right-hand side of the latter equation, depending whether the pitch error $\triangle p$ is − ve or + ve respectively.

For brevity the effect of pitch errors on the screw only has been considered in this section. A similar analysis may be made of the effect of pitch errors on the acceptability of a nut, bearing in mind that the effect of pitch and flank angle errors is to make the

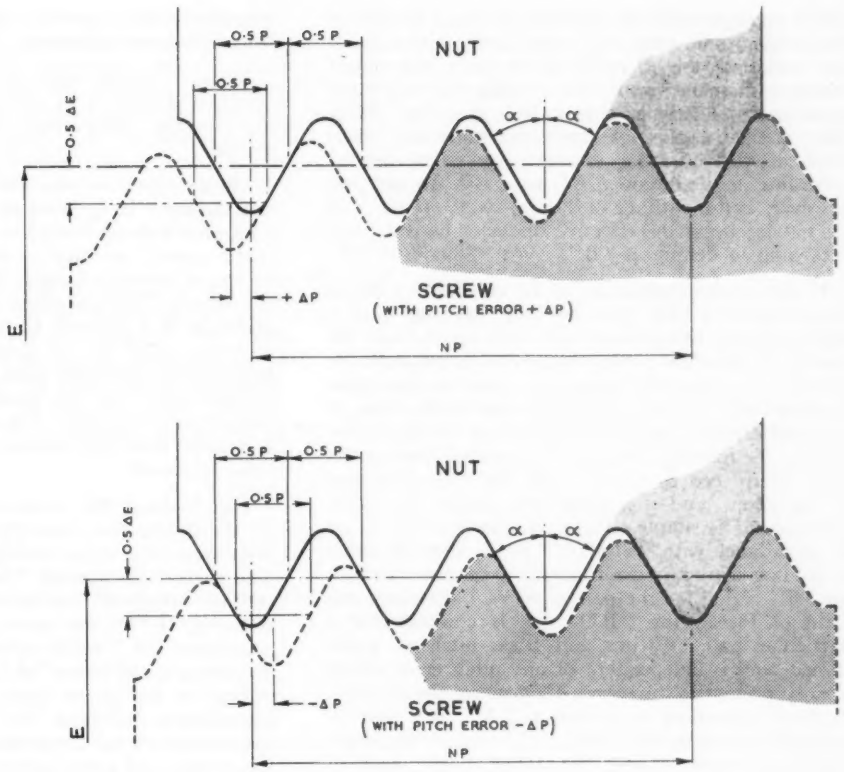


Fig. 4

virtual effective diameter of a nut smaller than its simple effective diameter.

6. inspection of screw threads

It has already been mentioned that if a screw thread has no pitch errors then the effective diameters according with definitions "A" and "B" respectively are the same. Unfortunately, many screw threads have pitch errors, and the difference between effective diameters "A" and "B" may be significant in relation to the inspection of screw threads.

The effective diameters of screw threads have to be checked to verify that they comply with the requirements (b) and (c) of Section 4. This inspection may be carried out by limit gauges or by direct measurement, and in this connection, the relative merits of the two definitions are given below.

In a limit gauging system, the "GO" screw ring gauge represents the "perfect nut" made to the maximum effective diameter limit of the screw it is intended to gauge, i.e., it represents the maximum permissible virtual effective diameter of the screw and checks that requirement (c) (Section 4) is satisfied. Provided that the screw assembles completely with the gauge it is immaterial which definition of effective diameter is adopted. Corresponding remarks apply to the "GO" screw plug gauge.

A "NOT GO" gauge for the effective diameter is intended to control the minimum metal limit of the effective diameter on the workpiece. In theory this gauge is designed to make localised contact with the flanks in the groove of the screw or nut at the pitch line of the gauge, i.e., it is designed to make contact with the flanks of the workpiece at a diameter defined by an intercept equal to one-half of the basic pitch in the thread groove of the screw or nut, this diameter corresponding to the effective diameter defined according to definition "B". In practice, the British Standard for screw gauges, B.S. 919 : 1952, specifies a length of thread of two to three turns of thread for the "NOT GO" effective diameter screw gauges and, in addition, although ideally the "NOT GO" gauges should not assemble with the work, they may on occasion, at the discretion of the inspector, be allowed to assemble by not more than two turns of thread; this relaxation allows a limited amount of "bell-mouthing" at the end-faces of a nut, or "falling-away" at the end of a screw.

If the nut or screw were truly parallel, with no bell-mouthing or falling-away, then a "NOT GO" gauge of a size equal to the minimum metal limit

which engages with the end two turns of thread on the work would pass it as satisfactory although, if the workpiece thread had a pitch error, the simple effective diameter would be outside the minimum metal limit. Clearly, in this unlikely case the "NOT GO" gauge would not check the minimum metal limit of the effective diameter, whether defined according to definition "A" or "B". In general, however, bell-mouthing or falling-away occurs, and the gauge checks the effective diameter limit defined according to definition "B".

If the screw threads are to be checked by direct measurement rather than by limit gauging, and a high accuracy of measurement is required, then the customary practice in this country is to measure the effective diameter by means of wires used in conjunction with an external comparator in the case of external threads, and by means of an internal comparator for internal threads. For external threads the wires are placed in contact with the thread grooves of the screw and meansurements under the wires are made. The simple effective diameter of the screw in accordance with definition "B" is then obtained by adding to these measurements a certain constant, the "P" value for the pair of wires. [1] For any one form of thread the "P" value is constant for a particular pair of wires and basic pitch of screw thread, and is independent of any pitch error which may be present in the screw. To measure the effective diameter according to definition "A", it would be necessary to calculate the "P" value for each individual screw, taking the actual pitch error of the screw into account. Again, this would be an undesirable complication.

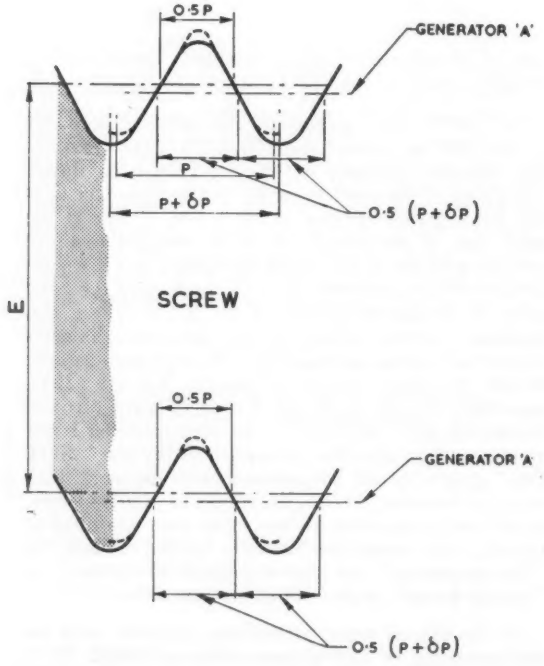


Fig. 5

Similar remarks apply to the measurement of the effective diameters of internal threads by means of an internal comparator using spherically ended styluses.

On the Continent the method of effective diameter measurement using wires is not in such common use as in the United Kingdom and the U.S.A., and in many cases it is usual to measure the effective diameters of external threads by means of a toolmaker's microscope. The procedure adopted is to superpose a graticule of a nominal thread form on the image of a thread *ridge* on one side of the screw, and then traverse the worktable until the nominal thread form is superposed on the image of the thread *groove* diametrically opposite. The effective diameter is then calculated from the distance through which the worktable is moved.

Fig. 5 shows the nominal thread form, indicated by the dotted line, superposed in the above way on both sides of a screw which has a pitch error $+\delta p$. The diametral distance "E" indicates the distance through which the worktable has to be moved. This distance "E" is the same as that between the two generators "A" which define the effective diameter according to definition "A". Measuring effective diameters in the above way gives effective diameters according to definition "A". Likewise a screw thread micrometer of the type which has a conical end to the spindle and a vee-notched anvil measures effective diameter "A" and not "B". To obtain effective diameters according to definition "B" in these two cases would entail making a correction for the pitch error.

From this viewpoint definition "A" is preferable to definition "B", but it must be remembered that toolmakers' microscopes and screw thread micrometers have an appreciably lower accuracy of measurement than that attainable by the use of thread measuring wires, and accordingly the difference between the two definitions becomes of less significance.

An idea of the difference in size between effective diameters "A" and "B" may be gained by reference to a particular screw thread, such as a $\frac{1}{4}$ in.-20 UNC screw made to the Class 1A tolerances given in B.S. 1580 : 1953. The effective diameter tolerance of this screw is 0.0056 in. If the whole of this tolerance were absorbed by the diametral equivalent of the pitch error, then this pitch error would amount to 0.0032 in. over the length of engagement of the nut with the screw. Assuming that this length is $\frac{1}{4}$ in., then the number of turns engagement n is five.

From equation (1) $$Y = 0.5 \frac{\Delta p}{n} \cot \alpha$$

$$= \frac{0.0032}{2 \times 5} \times 1{,}732$$

$$= 0.00055 \text{ in.}$$

i.e. Y is about 10% of the work tolerance.

It is, of course, unlikely that the effective diameter equivalent of the pitch error would absorb the whole of the effective diameter tolerance. It may well happen, however, that the diametral equivalent of the pitch error amounts to one-half of the effective diameter tolerance, in which case the difference in size between effective diameters "A" and "B" is about 5% of the effective diameter tolerance, an amount which is still significant and might lead to disputes unless a common definition of effective diameter has been agreed.

From the above information the conclusion is drawn that the maximum difference which can occur between the sizes of effective diameters "A" and "B" of a screw thread is not of such a magnitude as to affect the strength of the thread to a significant extent, but it is large enough to cause disputes between inspectors unless a common definition of effective diameter has been agreed. Definition "B" is preferable to definition "A", because it facilitates the inspection of screw threads by the methods commonly used in this country, which are more precise than the methods used to determine the effective diameter "A". As mentioned earlier, definition "B" corresponds to that given in B.S. 2517 : 1954, "Definitions for use in Mechanical Engineering".

acknowledgments

The author wishes to acknowledge the useful discussions he has had on this matter with M. C. A. Le Bourhis, of the Laboratoire Centrale de l'Armement, Paris, and Mr. Eric Green, of the National Research Council, Ottawa.

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REFERENCE

1. "Gauging and Measuring Screw Threads." *Notes on Applied Science*, No. 1, H.M.S.O., 1958.

Engineering Inspection and Non-Destructive Testing

A national conference on engineering inspection and non-destructive testing is to be held in Oxford, in September, 1961, to discuss the function of management in relation to inspection, the economics of inspection and non-destructive testing, and the recruitment, education and training of inspection staffs.

The conference is being planned at the request of the Joint Committee of Materials and their Testing and the British National Committee for Non-Destructive Testing. It is being organised jointly by The Institution of Engineering Inspection and The Society of Non-Destructive Examination, and the speakers will all be closely associated with their subjects and have wide experience in the fields concerned. Sessions will be arranged to allow ample time for discussion.

Residential accommodation at Queens College and New College, Oxford, has been reserved over the period 5th - 8th September, and the total cost, including conference fee, accommodation and all meals in College, will be £9 10s. per delegate.

Further information may be obtained from:

The Oxford Conference Secretariat,
The Institution of Engineering Inspection,
616 Grand Buildings,
Trafalgar Square, London, W.C.2.

QUALITY ON THE SHOP FLOOR

by S. W. NIXON, M.Sc., M.I.Prod.E.

Member, Control of Quality Sub-Committee

THE processes of production provide the acid test of the preparatory work which has gone into the design, provisioning, and production engineering of the product. To the degree that this work has been successfully carried out, and supported by adequate care on the part of the production operators, product quality will be reliably consistent, with all the benefits this confers.

At the risk of tedious repetition, the problems resulting from failure to secure consistent production to specification requirements cannot be too strongly emphasised. These include :

(a) excessive inspection cost involved in sorting mixed quality work;

(b) excessive cost of scrap and/or rectification of defective work;

(c) disorganisation due to contraction in the volume of work going forward; and

(d) danger of defective products going forward to the customer, and possibly giving rise to abnormal service costs.

In scrap alone £2 per week per productive operator is a very conservative figure for the average cost, in metal working concerns. Very few firms today would be unable to arrive at their own figure for this. The existence of wastage of this order is surely sufficient reason for a concentrated effort to improve the quality emerging from the processes of production. It is suggested that simple and inexpensive enquiries on the shop floor would immediately expose opportunities for improvement, and that no great difficulty need be involved in reducing this wastage by 50% or more. It may be that some improvements may entail an increase in operation cost, or necessitate capital expenditure, but undoubtedly there are many which would show an immediate "profit".

Shop floor investigations into the causes of scrap, with a view to corrective action, are not necessarily the prerogative of large concerns. Such enquiries can be carried out just as effectively by a single person, as by a fully-fledged investigation or efficiency department. The basic requirement is a willingness to accept that improvement is possible, and in fact will be achieved.

the primary task

The primary task of any quality control function is, of course, inspection on the shop floor. A most important by-product, however, is the information which is readily available relative to current levels of quality being encountered. Factually recorded and promptly disseminated to interested departments, such information is all that should be necessary to generate corrective action of one sort or another, where this is obviously necessary.

A variety of means is available today for the verification of product quality during manufacture. These are related to the nature of the operation and its control, and include the following :

1. automatic control while the operation is proceeding, with automatic termination and possibly corrective feed back, or manual termination by the operator;
2. checking by the operator immediately the operation is terminated;
3. checking by an inspector; and
4. automatic inspection by an appropriate device.

A cardinal point which assumes considerable importance as the scale of production increases, is that inspection shall take place either during, or as soon after completion of the operation, as practicable. If this is carried out, any defect which develops will be exposed at the earliest possible moment, so that combined with immediate corrective action, the number of defective details in the pipe line is reduced to a minimum.

The question as to what extent production operators should check their own work, or share the checking with inspectors, is an involved one. It depends on several conditions, including the nature of the production operation and particularly as to whether any automatic cycle time exists, the degree to which the production equipment is loaded, and to some extent the method of payment, and the nature of the incentive in operation.

It is obviously not practicable for operators to check their own work in circumstances which would,

in fact, result in a reduction in the required rate of output. Furthermore, when some automatic traverse time exists, it may be more convenient for the production arrangements, if the operator is given other work to carry out during that time.

It is often argued that checking by production operators is desirable in order to encourage or recreate pride of workmanship, and a sense of responsibility for the quality being produced. Undoubtedly this can be so, and in appropriate circumstances operator-checking should be called for. With manually-loaded operations, the operator of necessity must handle each part or unit during production, and it is economically advantageous to combine checking with this handling. This naturally brings home to the operator that variation is taking place, which may be controlled within requirements by the exercise of appropriate care and attention.

Pride of workmanship, and a feeling of responsibility can be instilled, however, in other circumstances. Factors such as adequate training of operators, careful choice of incentive, and its operation, and the exercise of adequate production supervision can also contribute to this end.

importance of production supervision

The influence of the production supervision cannot be over-estimated. It is thought in many quarters, and quite erroneously, that quantity and quality are opposed. Actually the reverse is the case, and any efforts made to bring quality consistently up to requirements bring their own reward in increased quantities of acceptable work. Regrettably, the technical aspect of the supervision of production is often neglected or relegated to second place relative to chasing up quantities, and it is suggested that some attention to quality requirements could be equally or more rewarding.

The consistency of production to specification requirements has an important bearing on the technique of inspection which may be applied, and cost of same. *In toto,* therefore, the cost of any inspection activity is a fairly direct indication of the general quality of work emerging from the processes of production in question.

Where the quality being produced from operations is consistently to requirements, its verification either by operator, or inspector, can proceed on streamlined and economic lines. If carried out by an inspector, it can be on a patrol basis at appropriate intervals, so that each inspector so employed can cover a comparatively large number of operations.

Such a procedure must, of course, be supported by inspection services relative to first-off samples, and successive samples at suitable intervals, and also relative to gauges and equipment generally. The assurance of quality being produced on these lines is also increased by a checking service under appropriate authority, of the condition of production equipment, i.e., machine tools, fixtures, and production tools generally.

influence on variation

An important point to be borne in mind is that under such conditions of quality, any variations outside specification are normally likely to be few in number, and small in degree. In such circumstances, the influence on customer quality should such variations go forward under patrol inspection conditions, will probably be negligible. By contrast, where quality is inconsistent, variations outside requirements are more numerous, and much greater in degree, so that sorting must be carried out to eliminate this from the work going forward.

The control of quality on the shop floor has several facets additional to the primary function of inspection. These include verification of incoming supplies, chemical and metallurgical control of material and processes, functional testing, and investigation of defects. All these have a contribution to make to the overall aim of securing consistent conformance to the requirements of the specification.

Quality control is an overhead cost. Some of its functions can, however, help materially to improve the production performance on the shop floor, thereby reducing the direct cost, as well as the cost of verification, and increasing the assurance of customer quality.

This is a message top management cannot afford to ignore.

"QUALITY — ITS CREATION AND CONTROL"

Copies of the Institution's report on "Quality—Its Creation and Control" may be purchased from the Publications Department, 10 Chesterfield Street, Mayfair, London, W.1, price 11/- each, including postage and packing.

Quarterly Newsletter to the Institution

group visits overseas

At the request of member firms, PERA last year organised a tour of several American exhibitions and factories for a party of directors and senior executives from member firms. PERA's Education and Training Manager supervised the tour arrangements and accompanied this party during its 14 days stay in U.S.A.

Following the success of this first group visit, it has been agreed that the Association should in future organise such visits for member-firms' personnel. Negotiations are now in progress for a 14-day visit to Russia which, it is hoped, will include a tour of various industrial and research establishments in Moscow and Leningrad. Provisional arrangements have also been made for a visit to the VIIth European Machine Tool Exhibition to be held in Brussels in September, 1961.

Group visits considerably reduce travelling expenses and the cost of accommodation to each participant, who is also relieved of the difficulties and uncertainties usually associated with tours of foreign countries. At least one of PERA's linguists will normally accompany parties on such visits as an interpreter, to ensure that members obtain accurate technical information about foreign developments.

current research

The current research programme includes an investigation into milling operations which has already shown how cutter performance can be improved by using the correct cutting edge geometry and milling technique. Work on the use of radioactive techniques has shown that it offers great possibilities for the measurement of tool life in machining research.

Research into drilling has emphasised the importance of the effects of point thinning and drill stiffness in increasing drill life. Little information has hitherto been available on the actual relative machining characteristics of the so-called "free machining" grades of steels. However, an investigation recently completed by PERA compares the machining characteristics of a plain carbon steel and a free machining equivalent when both were subjected to the same heat treatments.

The effects of reaming conditions, reamer geometry and wear, on hole accuracy and surface finish are considered in another recently issued report. The investigation showed that reamer wear was significantly affected by the cutting conditions used. A valuable empirical formula relating wear to hole dimensions, number of holes reamed, and cutting conditions has been established.

Research into the cold extrusion of steel and other materials continues, and the programme has been extended to include an exploration of the possibilities of "warm extrusion". Further tests in a series of investigations into the life of blanking and piercing punches made from different materials have been carried out to determine the nature of punch wear

Dr. D. F. Galloway (right), **Director of PERA, discussing gear production in PERA laboratories with Ing. Karel Stepanek, a senior research worker at the Machine Tool and Metal Cutting Research Institute, Prague.**

Ing. Stepanek has been awarded a Czechoslovak State Prize for his work on the development of magnetic scales for such applications as checking the accuracy of gears and gear trains, determining errors in gear manufacturing machines, etc. The Perspex scale model shown at the left of the photograph is being used in connection with studies of the dynamic stability of the gear hobbing machine, on the right, during the course of sponsored research.

and the influence of various factors associated with press tool design and construction. The complete series of investigations into the life of blanking and piercing punches will be covered in six reports, of which the first four have already been issued to members. Work on deep drawing is yielding valuable information, and high energy and explosive forming techniques are now being developed beyond the experimental stage.

Research into problems of automation is being advanced by the construction of a special mechanical feed-drive simulator which will greatly facilitate the testing and further development of numerical control equipment. Attention is also being given to the dimensional control of workpieces in machining operations. Other machine tool researches embrace the performance of power presses and cylindrical grinding machines, hydrostatic slideways and the application of P.T.F.E. impregnated bronze to slideways; and the dynamic behaviour of boring bars, structures and other machine tool elements.

CORRESPONDENCE

From : **A. G. Thorburn, A.M.I.Prod.E.,**
Quality Control Engineer,
Distington Engineering Co. Ltd.,
Workington, Cumberland.

MR. J. CHERRY's article on the economics of cutting processes and the discussion following, published in the February issue of *The Production Engineer,* was extremely interesting.

Most of it has been gone over before and on the theory that constant dripping will wear away a stone, it should have percolated into the minds of Machine Shop Planners and Managers long, long ago.

Of course, it hasn't and what we need is not another F. W. Taylor but a super salesman, who can explain the whole theme in words of one syllable and divorce the fearsome symbolic equations of the mathematical language and record them in arithmetical notation of $2 + 2 = 4$.

It may take a page or two to put it into language that those to the left of the norm can understand, as against a tight little algebraical equation readily understood by the right wing, but as an ex-Machine Shop Manager I know it must be done to get results.

To name a few, and a few only, who have laid down theories from practical experiments, we have :

1. "On the Art of Metal Cutting." F. W. Taylor. Proceedings ASME, 1957.
2. Manchester Society of Engineers. Lathe Tool Research Committee Report, 1922. (*H.M.S.O.*)
3. "A Manual of Cutting of Metals." ASME, U.S.A.
4. "Estimating and Planning." P. S. Houghton (which is No. 3 in British Terms and E.N. Numbers for the Various Steels).
5. "The Action of Cutting Tools." Chisholm, Lickley and Brown. (*Machinery Publishing Co.*)

No need to quote any more unless Stabler's "Original Researches into Cutting Tool Nomenclature", now under fire by I.S.O., are included.

In the discussion that followed Mr. Cherry's Paper, Mr. Cooper showed he clearly saw the problem of getting the knowledge in understandable terms on to the shop floor.

On Mr. Blache's question : "Does any firm use the knowledge?" The answer is "Yes". I know of two !

On Mr. Walker's comments, the real question to be answered is : "The most economic production cost". This takes in conformance to specification and quality, as Mr. Cherry said in slightly different words.

I would like to go on and make comments on all questions, which do in fact raise other questions, but will content myself with disagreeing with Mr. Cherry on chip thickness.

Chip thickness to me is feed/rev./plan approach angle, the resultant of all three—the chip thickness to be measured normal to the face, as it would most easily be measured.

However, to a Ratefixer, feed rev. is his chip thickness. To a Shop Foreman, who is also concerned with tool wear, maintenance of tolerance bands, horsepower, chatter and what the drawing asks for, including top rakes and nose radius, etc., chip thickness is the thickness measured normal to the face.

I am on debatable ground here, so to offset the destructive criticism, I append a Case Study distributed around Machine Shop Foremen some years ago. Prices of tools should be amended for present-day use. Throw-away tips show a saving on regrinding and machine break-down time and my calculations, theoretical of course, gave me some two years ago a reduction of tool cost per hour from 2s. 1½d. to 1s. 6½d. These costs are only true for one particular factory, as overheads affect machine hour rates and therefore the final result and economic tool life.

CASE STUDY

1. On machining operations, a tool life between regrinds of from 1 hour to 1½ hours for simple set-ups, such as a single tool in a centre lathe, should apply. This is accepted as a basis for an economic tool life by such authorities as Taylor*, A.S.M.E. and the Lathe Tool Research Committee of the Manchester Society of Engineers.

2. Calculating this standard tool cost per hour from a 1 hour basis, we have :

	s.	d.
Cost of a ¾ in. × ⅝ in. H.S.S. butt welded tool = 7s. 6d.		
Cost of a 1¼ in. × 1 in. H.S.S. butt welded tool = 12s. 6d.		
Cost of average tool used on centre lathe, say ... ... =	10	0
Time to regrind off hand per regrind, approximately 3 minutes.		
Number of regrinds before tool is consumed at .015 in. per regrind = 20. Therefore total life is 20 hours.		
Total price of tool maintenance = 3 min. × 20 min. = 60 min. 60 min. at 15s. 0d. per hour (machine idle time) =	15	0
Overheads on pedestal grinder plus grind wheel consumption ... ... =	2	6
Total cost of tool over 20 hours life ... =	27	6

Tool cost per hour = 27s. 6d. divided by 20 = 1s. 4½d.

3. Taking the tool cost per hour of a repetition job at present in production, it is found that we use two 5 in. dia. 10 teeth Galtona inserted tooth face mills on a job, working simultaneously at a surface speed of 84 ft./min. (65 r.p.m.), feed of 2¾ in./min. giving cut per tooth of .0039 in., and that these are changed four or more times per 8½-hour shift, say, every 2¼ hours.

Cost of one Galtona 62/14 tip is 7s. 6d. = £3 15s. 0d. per cutter or £7 10s. 0d. per set up.

Number of regrinds before tips are moved out in serrations at .015 in. per regrind is four - five. These can be moved twice before new tips are required, giving a total number of regrinds as 12 - 15; say, 14, a very conservative estimate on this job.

Then total life of tool is 14 hours × 2¼ hours = 31½ hours and tool cost spread over 31½ hours would be as follows :

	£	s.	d.
2 sets of 10 teeth, 20 teeth at 7s. 6d. each	7	10	0
14 × 2 regrinds 30 min. each at 12s. 6d. per hour	8	15	0
6 times remove tips and re-insert 30 min. at 9s. 2d. per hour ...	1	7	6
3 times cylinder grind, 30 min. at 12s. 6d. per hour		18	9
3 times surface grind, 30 min. at 12s. 6d. per hour		18	9
14 times 10 min. (machine idle time for change cutters) at 15s. 0d. per hour	1	15	0
Cost over total tool life of 31½ hours ...	£21	5	0

Therefore cost per hour 425 divided by 31½ = 13s. 6d.

This tool cost of 13s. 6d. per hour is a conservative estimate as the tool life is considerably decreased by striking hard spots in material.

4. Equating the standard tool cost of 1s. 4½d. per hour to the milling operation given above, the tools would require to last a total time of $\frac{£21.25}{\text{1s. 4½d.}}$ hrs. = 309 hours or a tool life between regrinds of : total tool life/number of regrinds to consume = $\frac{309}{14}$ hrs. = 21.1 hrs. tool life between regrinds. While an increased tool life between regrinds of this nature, i.e., 2¼ hours to 22 hours, would necessitate a reduction in cutter peripheral speed and therefore possibly also the feed in inches per minute to equate the tooth load, it would not necessarily be a proportionate reduction. There would also be a saving of 10 times 10 min. change cutter time to offset loss of production.

5. The relationship between tool life and cutting speed was first given by F. W. Taylor in his reports to the A.S.M.E. in 1907, "On the Art of Metal Cutting". The expression given for steel is :

$$VT^n = C$$

Where V = Cutting Speed in F.P.M.
T = Tool life for 1 minute
$n = \frac{1}{8}$

Other experimenters, including the Lathe Tool Research Committee, have confirmed the general expression.

Abstracting figures from that expression to increase tool life between regrinds from 1 hour to 22 hours means a reduction from 84 f.p.m. to 60 f.p.m., but it is known that an increase in cut per tooth can be made from .0039 in. to .005 in.

Taking these figures r.p.m. would be reduced to 46 r.p.m. and at .005 in. per tooth the feed would be 2.3 in. per min., a loss of .2 in. per min. or, in this case, for a full length feed of approximately 25 in. a loss of 2 min. per cycle (eight components are produced per cycle.)

6. Comparison of production costs :

1st Case Actual	*2nd Case Theoretical*
Production averages 176 per shift of $8\frac{1}{2}$ hours less 4 times 10 min. tool changing = 40 min. or 176 per $7\frac{5}{6}$ hours = $22\frac{1}{2}$ per hour. (Cycle time = $21\frac{1}{4}$M per 8 off.)	New cycle time = $21\frac{1}{4}$ + 2M = $23\frac{1}{4}$ per 8 off production per shift of $8\frac{1}{2}$ hours. (No lost time for cutter changing) = 174 or 20.6 per hour.
Cost per hour. :	Cost per hour. :
s. d.	s. d.
M/c hour rate = 15 0	M/c hour rate = 15 0
Tool hour rate = 13 4	Tool hour rate = 1 $4\frac{1}{2}$
28 4	16 $4\frac{1}{2}$
divided by $22\frac{1}{2}$ = 1s. 3d. each.	divided by 20.6 = $9\frac{1}{2}$d.

It should be noted that if no increase to the cut per tooth from .0039 in. to .005 in. is made, the production would then be 18 per hour at a cost of 10d. each.

7. Enough has been shown to point out that original tool cost, total tool life and total tool maintenance cost must be considered before deciding on an economic tool life between regrinds and that shop supervision, detail planners, and production study should examine all particulars using the various speed factors, and tool life charts provided. This tool life between regrinds, before tool cost can be reduced to reasonable proportion, apparently must be in the ratio of 27s. 6d. to 20 hours or 1s. $4\frac{1}{2}$d. per hour total tool cost.

For further interest the following worked example of how long a tool should run without regrinding for minimum production costs should be examined. The actual present day cost of tool and the actual machine hour rate of the particular machine being used should always be borne in mind.

*From $R = 145.76 \frac{N}{N+1}$

where R = best rate of doing work
N = 8 times

The time lost in changing tools
The time for regrinding
The equivalent of tool steel consumed
} All equated to the machine hour rate

EXAMPLE

Machine hour rate = 20s. 0d. per hour or 4d. per minute
2 Galtona 10 tooth Face Mill Cutters in use together and the following information is known.

	s. d.
Time to change 2 cutters, 10 min. at 4d. per min. ... ... =	3 4
Time to regrind 2 cutters, at 30 min. each at 15s. 0d. per grinding machine hour ... =	15 0
Equivalent of tool steel consumed, 1/14 of 20 teeth, at £7 10s. 0d. for 20 teeth = 150s. 0d. divided by 14 ... ... =	10 9
	29 1

and 29s. 1d. × 8 = 232s. 8d. divided by 20s. 0d. machine hour rate $23\frac{1}{3}$ hrs. between regrinds.

This method can be used to average every machine in the factory or average sections.

The tool cost per hour can also be averaged out for all sections and a chart run out showing monthly cost of tools per hour against the calculated datum. This method will show up just how bad things are and act as a spur to investigation.

A.G.T.

REFERENCE

*TAYLOR, F. W. *On the art of metal cutting.* Proc.A.S.M.E., 1907.

Correspondence and comment on published Papers and matters of interest to production engineers are invited.
Communications should be addressed to :

THE EDITOR,
" THE PRODUCTION ENGINEER,"
10 CHESTERFIELD STREET,
MAYFAIR, LONDON, W.1.

VISIT TO E.M.I. RECORD FACTORY

reported by

R. H. NORRIS,* A.M.I.Mech.E., A.M.I.Prod.E., A.F.Inst.Pet., and

B. L. SOANES,* A.M.I.Prod.E., A.M.I.M.E.

A PARTY of 16 production engineers, including members of the London Section of the Materials Handling Group of The Institution of Production Engineers, visited the Record Factory of E.M.I. Ltd., on 2nd March, 1961, to review some aspects of materials handling related to the manufacture of record discs. The party was received by Mr. E. G. Breed, E.M.I. Factory Visits Section.

During the introductory session members were informed by Mr. Breed that about 96% of the works' production was concerned with the manufacture of 45 r.p.m. and 33⅓ r.p.m. vinyl thermo-plastic long-play records. Less than 4% of the production was devoted to the manufacture of the old-type 78 r.p.m. shellac records, which were still being exported to certain areas. Both batch and mass production methods were employed to satisfy the sales demands for individual discs.

Prior to manufacturing record discs, studio recordings were made on high fidelity tape recording machines, thereby ensuring the accurate transcription of sound waves into electrical impulses. The tapes were then transferred to special purpose sound track groove cutting machines where precision grooves were cut on a cellulose disc, with an aluminium core, by electrical styli. Both Monaural and Stereophonic tracks were cut in this manner.

The aluminium cellulose discs so produced were known as "lacquers". These discs were sprayed with a silver solution to obtain an electrical contact, and immersed in plating baths, first of nickel and then of copper, and plated to thickness limits to form master discs. Further processing was necessary to produce positive "Mother" discs and finally, grooved nickel plated matrix discs thinly coated with chromium were prepared for use in the record presses. This complex process was discussed with Mr. Breed and then the following main production departments were inspected:

1. mixing of long-play record materials

The 45 r.p.m. and 33⅓ r.p.m. long-play record discs are manufactured from specification vinyl-resin compounds. Continuous process flow lines are used for producing the basis discs materials:

Stage 1. Vinylite compound material is pre-heated in a hopper type mixing unit.

Stage 2. Material rolled, first operation, in a special purpose heated rolling mill.

Stage 3. Material then rolled, second operation, in a special purpose heated rolling mill to final size, rolled strip.

Stage 4. Material in strip form is transferred to a water cooling unit, as required to harden the rolled strip.

Stage 5. Material in hardened strip form is machined into small granules and packed into containers; or

Stage 6. Material in hardened strip form is broken into "biscuits" and packed into containers.

Materials handling is efficiently arranged by using power-driven belt conveyors to transport the material to the processing stages. In the case of "biscuit" production, the strip is manually broken up into sections, prior to packing in special containers.

2. pressing of long-play records

The design and layout of the machine tools in the extensive process shops requires the use of "biscuit" materials. Only limited use is made of granular materials on some new-type experimental process machines. The process lines per operator for 10 in. and 12 in. records are as follows:

Stage 1. Preheat "biscuits" in preheater unit.

Stage 2. Press "biscuits" in preheated presses to form grooved discs and fix record labels (2 machines).

Stage 3. Trim edge of disc on special purpose disc trimming machines (1 machine).

Stage 4. Stack discs on spigot type transporter plates.

Stage 5. Load transporter plates to suspended trays on mono-rail power-driven conveyor.

In this system one operator controls a preheater unit, two presses and one edge trimming machine. Both biscuits and discs are manually loaded to the machines and transport plate. Stacked "biscuits" are transported from the stores to Stage 1 on an electric truck which is manually operated. Also at Stage 5, the transporter plates are loaded manually on to suspended trays on the mono-rail power-driven conveyor.

* Committee Members, London Section, Materials Handling Group.

E.M.I. Robotug Driverless Trolley

The process lines per operator for the smaller 7 in. discs are as follows:

Stage 1. Preheat "biscuits" in preheater.
Stage 2. Press "biscuit" in preheated press to form grooved discs and fix record labels (1 machine).
Stage 3. Trim edges on power press (1 machine).
Stage 4. Stack discs on spigot type transporter plates.
Stage 5. Load transporter plates to suspended trays on mono-rail power-driven conveyor.

As with the previous system, stacked biscuits are distributed from the stores to Stage 1 on an electric truck which is manually operated, the transporter plates being manually loaded to the suspended tray conveyor. The moving conveyor is located down the centre of the press shop to facilitate manual loading on a continuous cycle from the press units. The suspended trays were designed to incorporate a five-station pneumatic pre-selector remote controlled unit, and the conveyor also acts as a "live" store.

3. inspection and packaging

Prior to visual inspection and packing the stacked discs are transported by the conveyor to the paper cover stores. Batch blocks of selected paper covers are manually loaded on to the centre spigot of the transporter plates. The stacked discs are then transferred to trays on a continuous conveyor, from which the stacks are taken off as required by the examiners. Empty transporter plates are returned to the pressroom by means of the conveyor system.

All discs are inspected visually, placed in the correct paper covers and packed into cardboard boxes, manually. By utilising power-driven slat type conveyors, the packaged units are transported to the upper floor main record stores.

4. record storage and despatch

The box units from the conveyor are transported manually by trucks to selected storage racks. Minimum stock per record batch varies from 25 to several thousand discs, dependent upon orders and sales demands. Following receipt of order and authorisation for despatch, the box units are manually selected and re-routed to the lower floor packaging department. Hand pallet trucks and gravity chute conveyors are used to ease handling from upper floor stores to the lower floor department. Finally, the box units are built up manually into packaged units and then transported by hand trucks to the works loading despatch bays.

5. master disc and matrix stores

It is necessary to store approximately 176,000 master discs in fire-proof stores. The stores contain some masters dating back to 1904 - 1910, e.g., Melba, Caruso, etc. Matrix discs and labels are also stored for works' usage; transportation to the press shops is by a power-driven suspended tray elevator conveyor.

E.M.I. Robotug Driverless Trolley

Some time was spent studying the E.M.I. electric system of a battery operational remote-controlled truck built by Scott Electric Vehicles Ltd., Kidderminster. The unit inspected was capable of pulling a 3-ton load.

The utilisation of these vehicles could assist in speeding up materials handling operations particularly in areas where storage area requirements are continually changing.

During the final discussion session, **Mr. R. H. Norris** (*Mobil Oil Co. Ltd.*) said that one major aspect of machine materials handling in the record factory was the utilisation of the impressive five-station, pneumatic pre-selector, suspended tray power-driven mono-rail chain conveyor, used for transporting the pressed discs to the inspection and packaging departments. The use of this conveyor had undoubtedly assisted the handling of materials and improved productivity.

Mr. J. Weetch (*J. Lyons & Co. Ltd.*) commented that installation costs of such a system would undoubtedly be high, especially when considering the complexity of the five-station pre-selector units. Were the costs of the installation justified in relation to the benefits of improved materials handling?

In reply to Mr. Weetch, **Mr. Breed** said it was estimated that a considerable saving in manual handling time had been attained by using the conveyor unit. On a cost basis the conveyor system had proved to be an economic proposition. Previously the materials were transported manually by trucks which were expensive and inefficient. The initial conveyor system was installed during 1953 - 1954, being enlarged to accommodate five lines in the examination area in 1959. It was giving satisfactory service.

Mr. B. L. Soane (*Trojan Ltd.*) remarked that an additional feature of the conveyor system appeared to be the cost savings made by using the conveyor as a "live" store, this being an important feature in saving valuable floor space. Presumably this factor had also been investigated prior to installation.

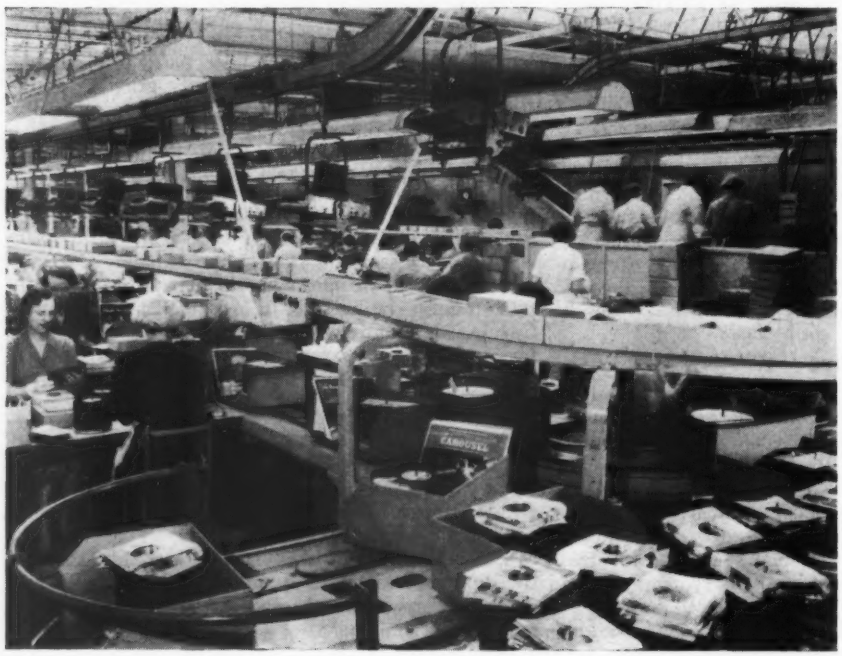
Mr. Mendelsson (*English Numbering Machines Ltd.*) said that during the works visit interest had been aroused in the "down time" required for changing the matrix on the disc pressing machines. Had any studies been made in relation to this factor which was virtually lost production time?

Mr. Breed replied that attention was being given to this problem. On an average 1,000 discs were produced per matrix. It was essential to change the matrix periodically to ensure an acceptable quality control of the finished record discs.

With reference to the 10 in./12 in. disc pressing systems, **Mr. Weetch** observed that the time spent handling the "biscuit" manually and also in transporting the "biscuits" to the presses, was relatively long. Were any improved methods of productivity under review to reduce the manual movements, thereby lessening operator fatigue and loss of production?

Mr.Breed, in reply, said that the use of "biscuits" in the production of discs was under continuous review. For example, the possibility of using granular materials and hopper feed devices could improve the material handling time. Also, extrusion processes might be used to advantage in this particular field; but one must not lose sight of the fact that the quality of the reproduction was of prime importance.

Mr. Mendelsson, referring to manually breaking up the "biscuits" from the vinylite rolled strip, asked if a mechanical method could be employed to save time and costs? Also, the precautions taken to exclude any dust or grit during packaging of biscuit materials were of interest.



General view of L.P. and E.P. inspection, showing conveyor system.

Mr. Breed said that all material handling processes in the manufacture of "biscuits" and discs were being investigated in order to improve productivity. It was essential to eliminate dust and grit from the materials to ensure a high standard of quality control on the finished products.

Mr. Norris, in conclusion, commented that the utilisation of modern materials handling methods and, in particular, the use of power-driven conveyors in the record factory, had fully demonstrated the cost savings that could be attained by these installations on a progressive basis, the ultimate objective being to improve productivity and reduce the overall costs of production. In winding up the proceedings, and on behalf of the Materials Handling Group, London Section, he thanked the Directors of E.M.I. Ltd. for the privilege of visiting the Record Factory.

A spontaneous vote of thanks was given to Mr. Breed and Mr. Startin for the assistance given in conducting the party around the works and for discussing the complex details of Materials Handling. Miss B. Trigg, Technical Committee Secretary, thanked them personally on behalf of the Institution for the hospitality and very pleasant day spent at E.M.I. Ltd.

Integrated Data Processing Conference

The Conference on Integrated Data Processing, organised last February by the British Conference on Automation and Computation, was heavily over-subscribed and as a result of many requests will be repeated on **Wednesday, 24th May, 1961,** in the Assembly Hall, Church House, Great Smith Street, Westminster, London.

The tickets cost £6 6s. each, inclusive of luncheon, morning and afternoon refreshments and a copy of the EPA Mission Report, with which the Conference is concerned. Applications should be addressed to : **The British Productivity Council (I.D.P. Conference), Vintry House, Queen Street Place, London, E.C.4.**

COUNCIL NOMINATIONS — see overleaf

PARTICULARS OF MEMBERS OF COUNCIL OF THE INSTITUTION 1961—1962

This information is given in accordance with Article of Association No. 37. It is compiled from details available up to 21st April, 1961. None of the members shown on this list should be nominated as an Elected Member of Council.

PRINCIPAL OFFICERS

President : H. Burke
Vice-President : R. Ratcliffe, C.B.
Chairman of Council : R. H. S. Turner
Vice-Chairman of Council : A. L. Stuchbery
Immediate Past Chairman of Council : H. W. Bowen, O.B.E.

ELECTED MEMBERS

The following Elected Members will continue in office for a further year from 1st July, 1961 :

G. V. B. Bevan	C. E. Darlington	P. G. H. Jeffrey
R. E. Leakey	J. G. Noble	P. J. Shipton
L. P. Simpson	J. W. H. Smith	J. H. Winskill

CHAIRMAN OF REGIONAL COMMITTEES ADDITIONAL REPRESENTATIVES ON COUNCIL

At the time of going to press the election of Regional Officers had not been completed.

COUNCIL NOMINATIONS

NOTICE OF COUNCIL ELECTIONS 1961—1962

NOMINATIONS

(a) In accordance with Article 43, nominations are invited to fill *nine* vacancies for Elected Members to serve on Council for 1961 - 1962 (i.e., eight Members and one Associate Member).

(b) Before candidates are nominated for election, their consent must be obtained.

(c) Candidates for election must be nominated in writing by three Corporate Members* of the Institution.

(d) In addition to nominations as in (c) each Section Committee may nominate one candidate.

(e) The nominees must give the full Christian names (or forenames) together with respective addresses of the person or persons they are nominating.

(f) The nomination must be accompanied by brief biographical notes of the person or persons who have been nominated.

(g) Nominations must be set out on a separate sheet of paper and not included in a letter dealing with other subjects.

(h) Nominations must be contained in a sealed envelope marked "Council Nomination".

(i) Nominations must reach the Secretary at 10 Chesterfield Street, Mayfair, London, W.1, not later than **Monday, 15th May, 1961.**

(j) The members listed below are due to retire and are not eligible for re-election as Elected Members until at least one year has elapsed.

Members

C. T. Butler; Prof. N. A. Dudley; B. H. Dyson; J. France; S. G. E. Nash; J. Silver; H. Unsworth; G. A. J. Witton.

Associate Member

R. S. Clark.

By Order of the Council,

W. F. S. WOODFORD,

Secretary.

MAY, 1961.

* Corporate Members are: Honorary Members, Members, Associate Members.

Mr. J. Bell, Member, has relinquished his position as General Works Manager with J. W. & T. Connolly Ltd., High Wycombe, and has taken up a new appointment as General Works Manager with Wolseley Engineering Ltd., Witton, Birmingham.

Dr. E. N. Corlett, Member, Senior Research Fellow in the Department of Engineering Production, University of Birmingham, has been awarded the degree of Ph.D. for his work on "Human Factors in Machine Control". Dr. Corlett serves on the Institution's Editorial Committee, and is a Corresponding Member of the Papers Committee.

Mr. W. G. Dorkings, Member, has been appointed to the Board of Nicholas Products Ltd.

Mr. E. H. Holder, Member, Principal Production Officer, D.A.W.P., London, has been transferred to R.P.E., Wescott, Bucks., in charge of Engineering and took up his new duties on 1st March, 1961.

Mr. C. R. Pal, Member, has been appointed Chief Construction Engineer, Coal Mining Machinery Project, Heavy Engineering Corporation Ltd., Durgapur.

Mr. L. S. Pitteway, Member, has resigned his appointment as Senior Lecturer in Management Studies at the Nottingham and District Technical College, to join an International Labour Office mission to East Pakistan.

Mr. D. Brunnschweiler, Associate Member, is now Production Director of Cornard Knitting Mills Ltd., Sudbury, Suffolk.

Mr. R. Clarkson, Associate Member, has relinquished his position as Director of C. Jackson & Son., Leamington Spa, to rejoin the General Electric Company (Telephones), Coventry, as Senior Methods Engineer.

Mr. R. J. Evans, Associate Member, has recently taken up the appointment of Head of Engineering at Wolverhampton Technical College. Mr. Evans, as Head of Engineering at Burnley Municipal Technical College, has been an active member of the Preston Section Committee for the past year.

Mr. J. S. Harman, Associate Member, has relinquished his appointment as Works Superintendent for Smiths Motor Accessories Ltd., Watford, and has taken up a new appointment as Works Manager for Progress (International) Ltd., at Shannon, Eire.

Mr. J. W. Haig-Ferguson, Associate Member, has been appointed Managing Director of R. & J. Beck Ltd., London, one of the Griffin & George Group of Companies.

Mr. E. E. Hempsall, Associate Member, formerly Central Production Manager of Renold Chains Ltd., has now been appointed General Works Manager.

Mr. J. C. Shapley, Associate Member, Works Manager, Hoover Ltd., Perivale, has just completed 25 years with the Company. In recognition of this long service, he has been presented with a gold watch by the Managing Director, Mr. Sidney Roberts.

Mr. J. R. Thompson, Associate Member, has now been appointed an Assistant General Manager at the Rolls-Royce Ltd., Derby Group of Production Factories. He was previously Assistant General Works Manager.

Mr. B. C. Baker, Graduate, has relinquished his appointment as Senior Tool Designer with S. Smith & Son Ltd. (England), Motor Accessories Division, Witney, Oxon., and has now taken up a position as a Senior Design Draughtsman with High Precision Equipment Ltd., Bletchley, Bucks.

Mr. R. F. Ferguson, Graduate, is now Head of Mechanical Engineering Services in the British Scientific Instrument Research Association.

Mr. W. R. Moule, Graduate, has relinquished his position as a Design Draughtsman with The Wulfruna Design Co., Wolverhampton, and has taken up an appointment as an Assistant Grade B Lecturer, in the Mechanical Engineering Department of the Wolverhampton and Staffordshire College of Technology.

Mr. J. A. Ross, Graduate, has been promoted to the position of Works Manager, Euclid (Great Britain) Ltd., Peterhead Gear Plant, Aberdeenshire.

Mr. R. L. Sunderland, Graduate, has relinquished his position on the design staff of Raleigh Industries Ltd., Nottingham, to take up the appointment of Product Development Engineer at Paton, Calvert & Co. Ltd., Liverpool.

Mr. M. C. Taplin, Graduate, formerly Designer at L. M. Van Moppes & Sons (Diamond Tools) Ltd., Basingstoke, Hants., is now Production Manager of Ghana Louvres Ltd., Accra, Ghana.

Mr. J. R. Trotter, Graduate, has relinquished his position as Production Editor of *Engineering*, to take up an appointment with Albert E. Reed & Co., at their Aylesford Paper Mills.

DIARY FOR 1961

MAY 5	**Wales Regional Conference, Cardiff.** Subject: **"The Conservation of Materials"**
MAY 9 and 10	**Standards Conference, London.**
MAY 24	**Region and Section Officers Conference, 10 Chesterfield Street, Mayfair, London, W.1.**
JUNE 14	**The 1961 Viscount Nuffield Paper, University of Bristol.** Speaker: **Sir Willis Jackson,** Director of Research and Education, A.E.I. (Manchester) Ltd. Subject: **"Some Human Aspects of Engineering Progress"**
JUNE 27 - 30	**B.C.A.C. Conference, Harrogate.** Theme: **"Automation, Men and Money"** (see Journal Supplement)
NOVEMBER 1	**Annual Dinner, Dorchester Hotel, London.** Principal Guest: **The Rt. Hon. the Viscount Chandos, P.C., D.S.O., M.C.**
NOVEMBER 3 - 4	**Materials Handling Convention, London.** Theme: **"Profit by Handling"**

Hazleton Memorial Library

ADDITIONS

Brown, Wilfred. **"Explorations in Management."** *London, Heinemann,* 1960. 326 *pages. Diagrams.* 30s.

"A description of the Glacier Metal Company's concepts and methods of organisation and management." The author has been Chairman of the Company for over 20 years, and this book is an inside account of the Glacier Experiment — a sociological and managerial experiment — studied by Doctor Elliott Jacques and described in his changing culture of a factory and measurement of responsibility.

Contents: Analysis of organisation — *Part* 1. *Structure.* Some organisational concepts — The executive system — The manager and his subordinates — Disagreements on executive matters — *Part* 2. *Policy.* Policy making and its effects — Managers and development work — *Part* 3. *Communication.* Contraction of executive lines — Written policy and communication — The manager and meetings — *Part* 4. *Specialist work.* Analysis of specialist work — History of our specialist problems — Specialist organisation — *Part* 5. *The gap at the bottom of the executive system.* The supervisor — Summary of relationships — *Part* 6. *Sources of managerial authority.* The representative system — The legislative system — The appeals procedure — Some unexplored problems — *Appendices.* Glossary of technical terms — Company policy document — Bibliography on the Glacier Project.

Haim, G. **"Manual for Plastic Welding."** Volume 3. **"Polyvinyl Chloride."** *London, Crosby Lockwood,* 1959. 324 *pages. Illustrated. Diagrams. Tables.* 50s.

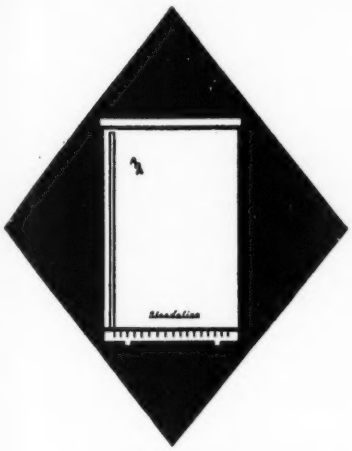
It is hoped that this comprehensive textbook on the welding of rigid and plasticised PVC will help to extend its use in industry. It includes extensive bibliographies and lists of British and foreign patents.

Contents: The chemistry and physics of polyvinyl chloride — Physical properties of polyvinyl chloride — Manufacture of polyvinyl chloride — Commercial forms of polyvinyl chloride — Cements — Historical development of polyvinyl chloride — Welding equipment — Other welding processes suitable for polyvinyl chloride —)Detailed information relating to the hot-gas welding of polyvinyl chloride — Equipment used in a workshop for the fabrication of polyvinyl chloride — General information for the working and forming of polyvinyl chloride — Lining of tanks and vats with unplasticised polyvinyl chloride — Polyvinyl chloride pipe lines — Polyvinyl chloride duct lines—Polyvinyl chloride in the building industry — Applications of polyvinyl chloride in industry — Training of welders — Glossary of terms used.

Say, M. G. (Editor.) **"Analogue and Digital Computers."** *London, Newnes,* 1960. 308 *pages. Diagrams.* 50s.

An attempt to produce a comprehensive and up-to-date summary of a rapidly changing subject. It is written by seven specialists, each of whom contribute chapters in his own field.

Contents: Introduction to computers — Operation and applications of analogue computers — Design of analogue computing systems — Analogue computing circuits — Number representation in digital computers — Operation of a digital computer — Circuit elements and computer units — Storage — Input-output equipment — Programming.



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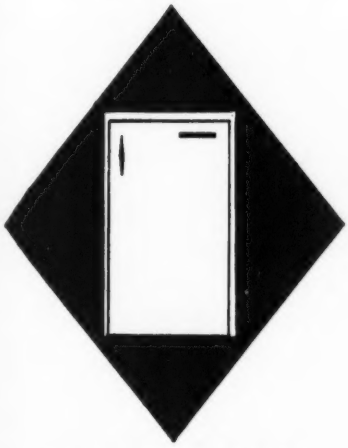
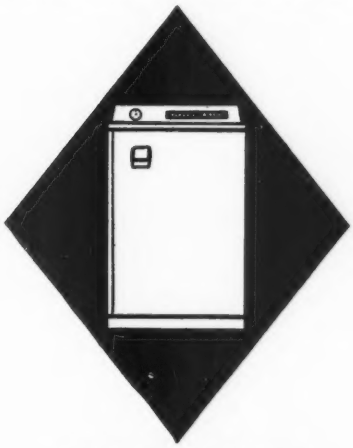
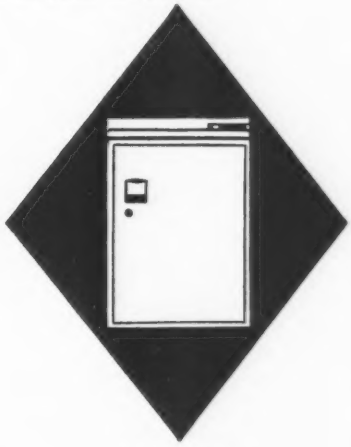


Frigidaire SheerLook DB-50



Morphy-Richards Astral A350



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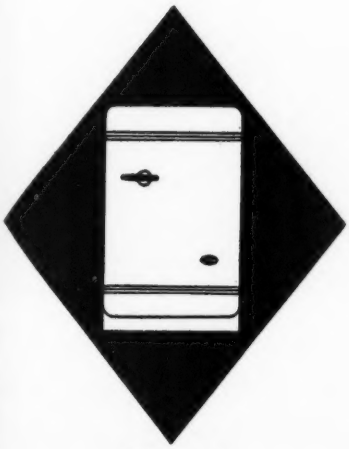

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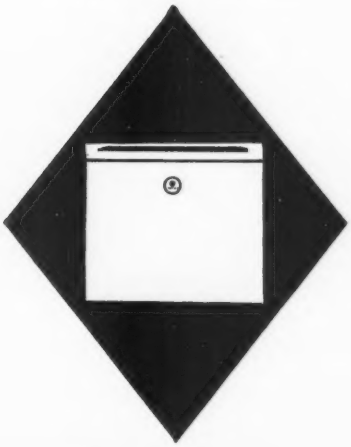

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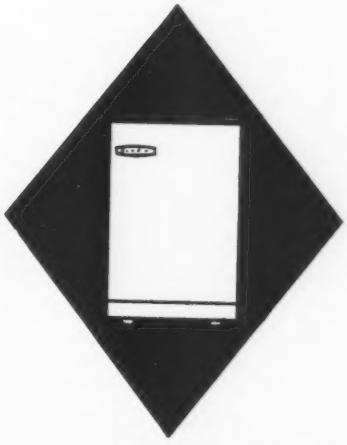

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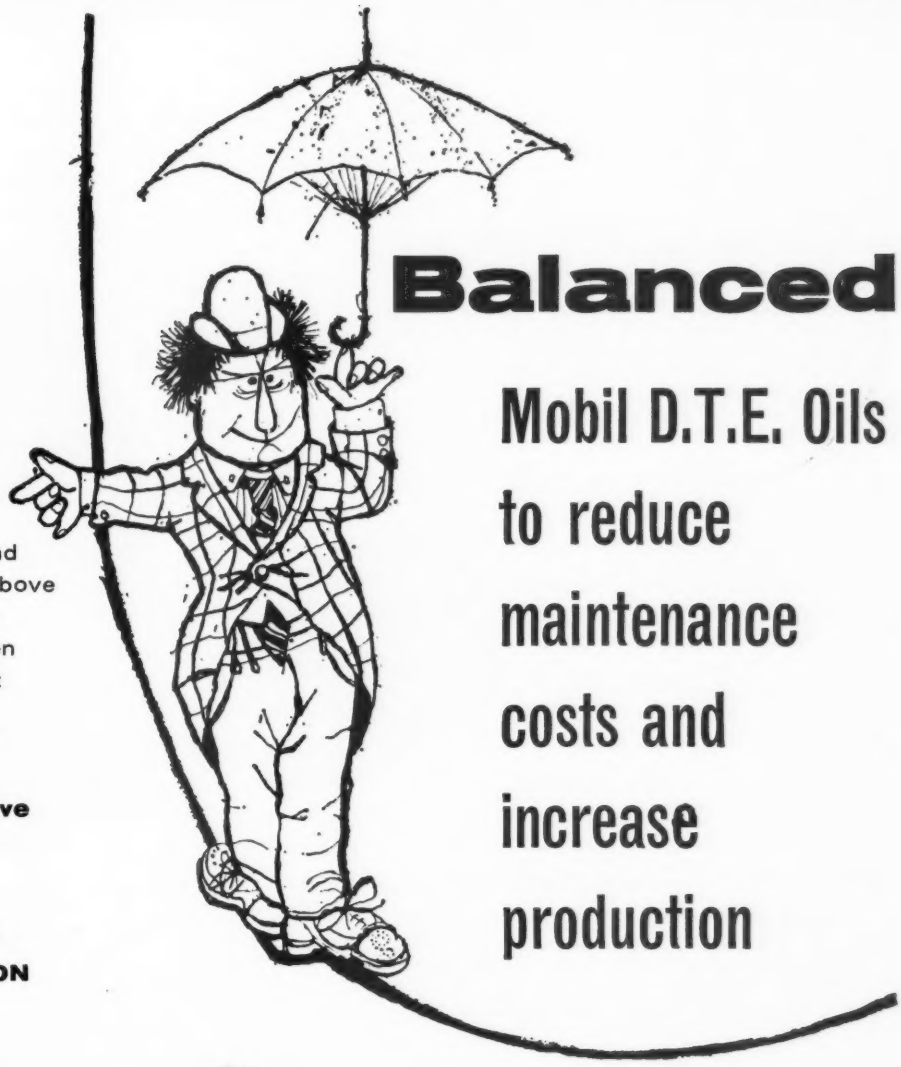

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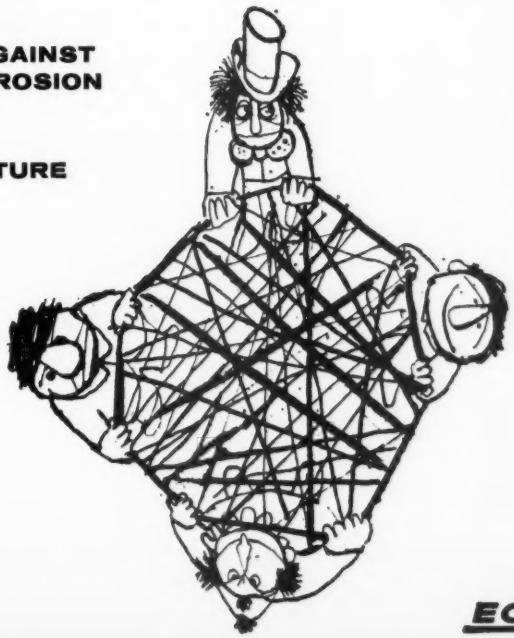

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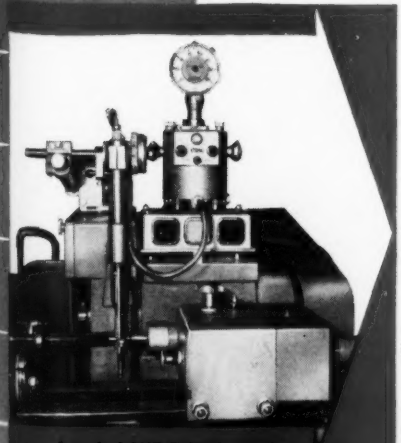

A typical OMT-ETAMIC grinding machine application. Final wheelhead infeed, finish diameter of splineshaft and wheelhead retraction are all controlled by the Automation Head.

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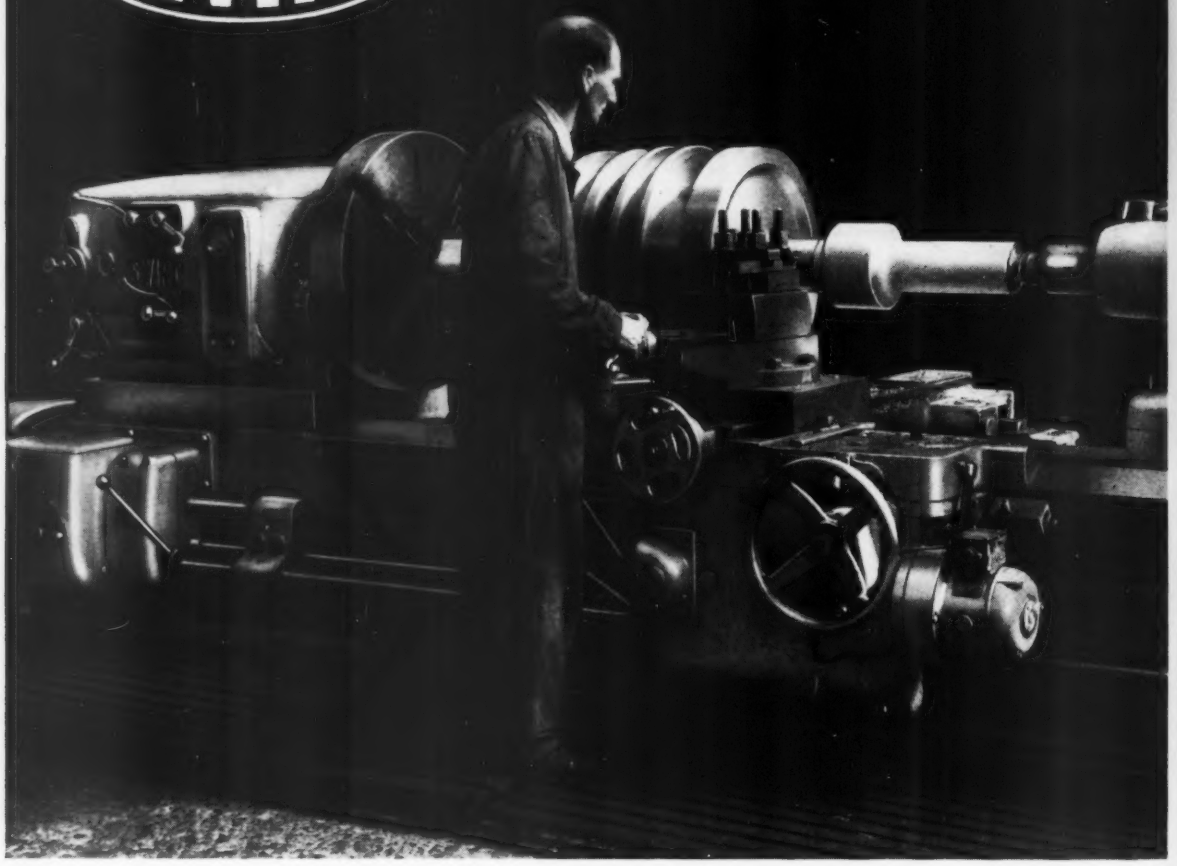

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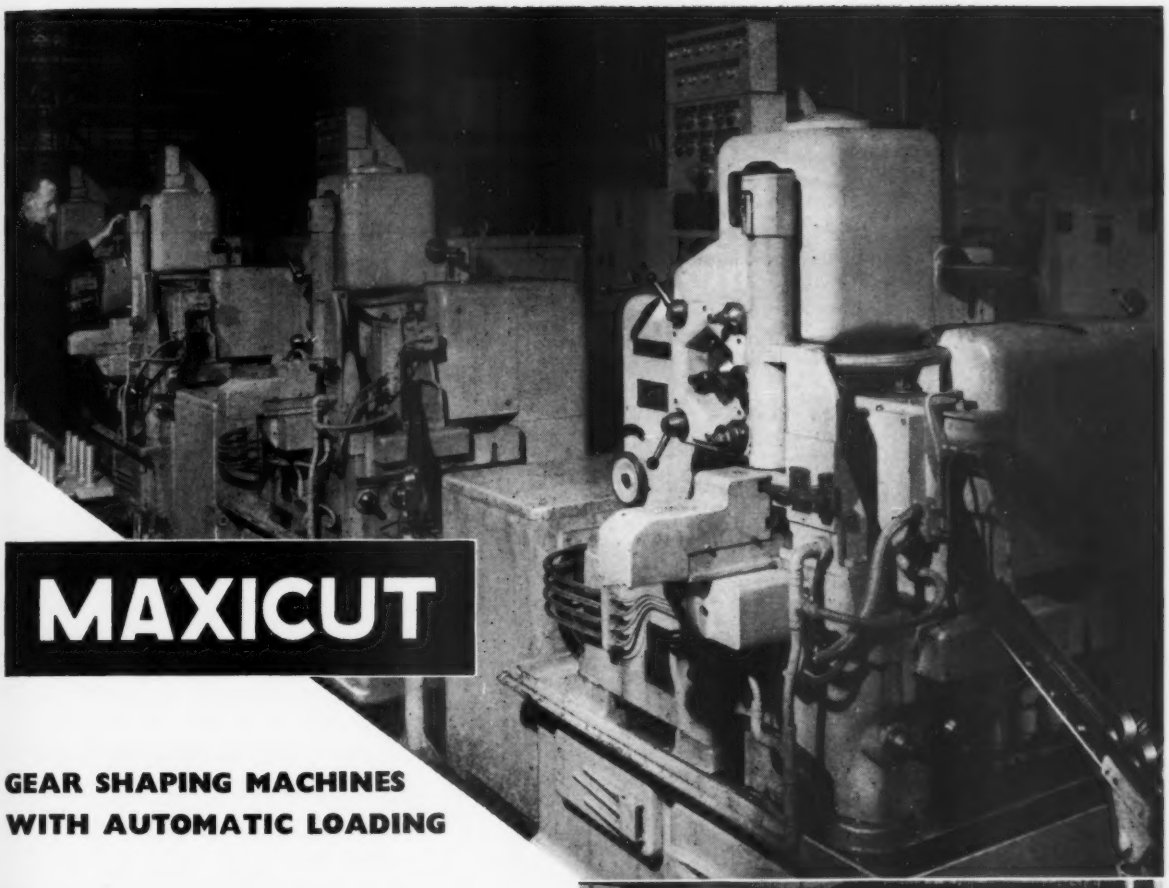

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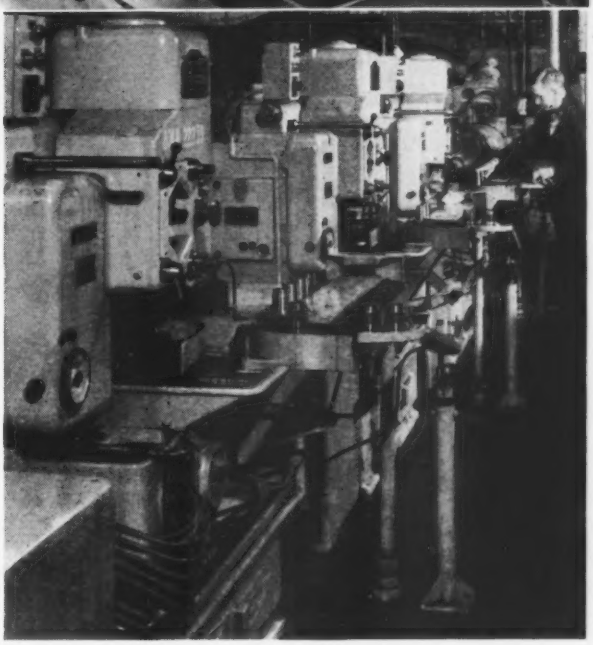
for mass production of automobile gears



These illustrations show two lines of Drummond No. 2A Maxicut Gear Shapers at the Austin Motor Co. Ltd., Birmingham. Machines in the top view are equipped with magazine loading and in the bottom illustration swinging arm type loaders are fitted.

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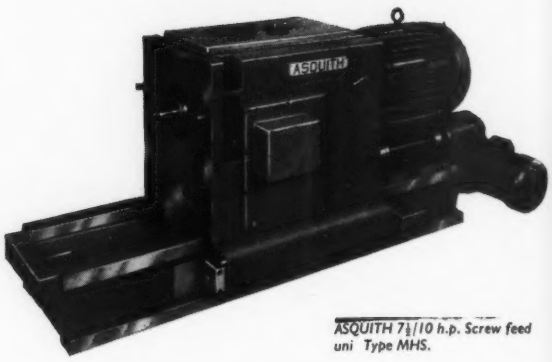

ASQUITH 7½/10 h.p. Screw feed uni Type MHS.

The example illustrated is a five station, rotary table machine for drilling, reaming and milling operations on automobile spring hangers. A vertically mounted 7½ h.p. unit is arranged with the milling attachment and a 2 h.p. unit with multi-head and bush plate is also mounted on a vertical column. Another 2 h.p. screw unit operates horizontally. The 3 ft. dia. hand indexed table incorporates an air lift feature to reduce operation fatigue and clamping is automatic. The table is controlled by the foot valve at the base.

If you manufacture components in large quantities which require several machining operations, it will pay to investigate the possibility of producing them on an Asquith Unit Type Machine. Units from ½ h.p. upwards can be applied for multi-way, rotary transfer and in-line transfer operation.

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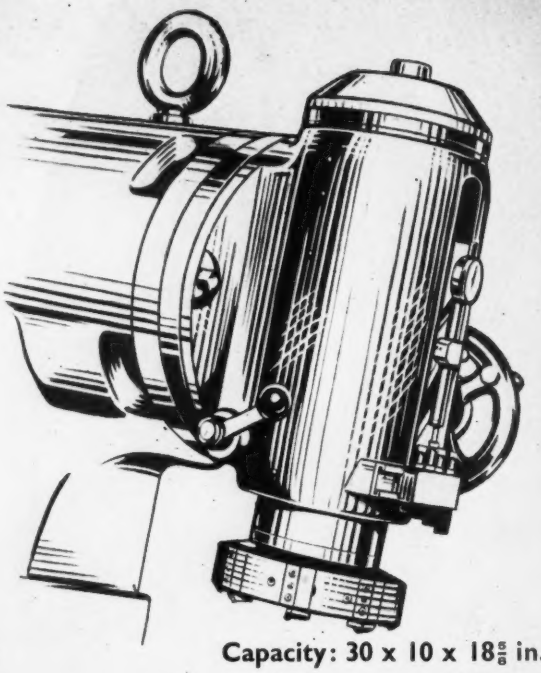

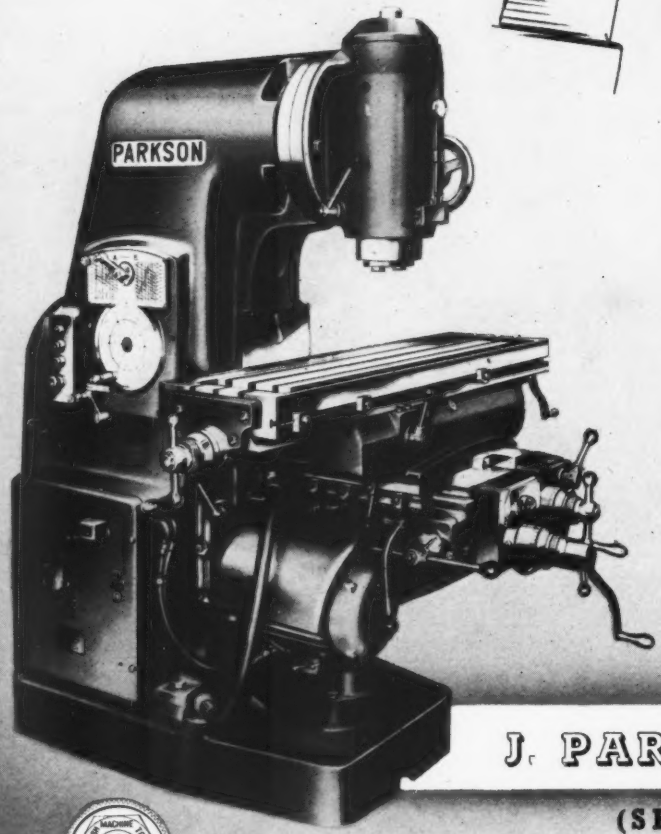

Capacity: 30 x 10 x 18$\frac{3}{8}$ in.

Power feeds and rapid traverse to all table movements

24 Spindle speeds:
18-1000 r p m
or 24-1330 r p m
or 27-1500 r p m

Spindle Nose: 5$\frac{1}{16}$ in. dia no. 50 taper hole

Range of
PARKSON
Horizontal Milling Machines
INA Universal
2N Universal
2N Plain
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Adapta Model N

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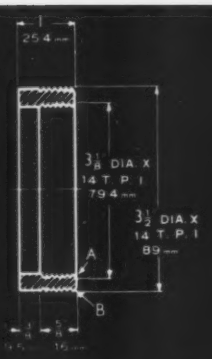
(SHIPLEY) LTD

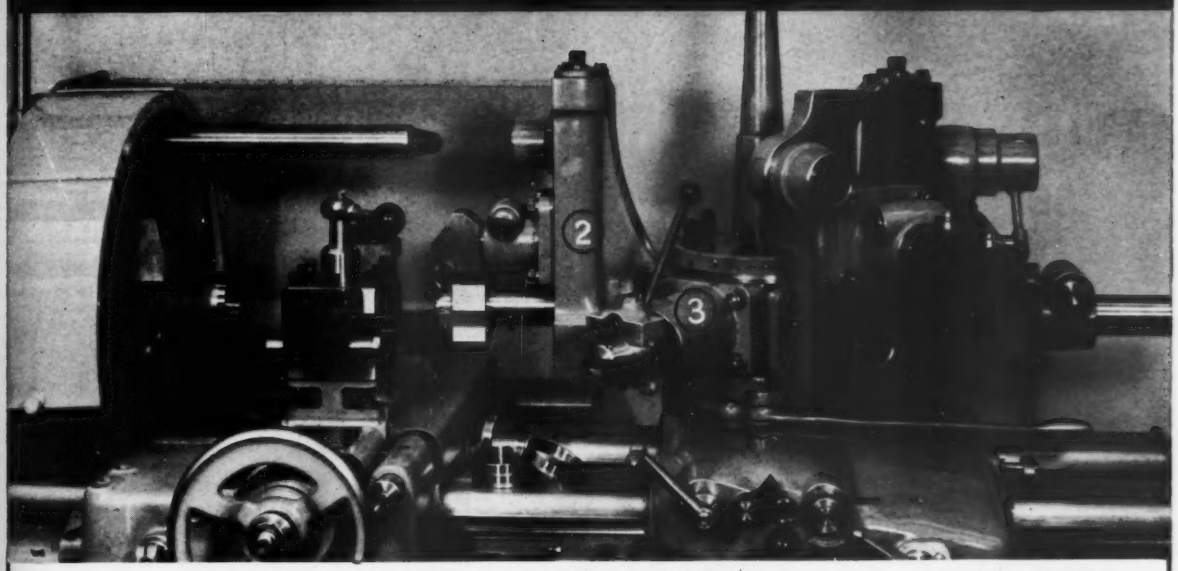
SHIPLEY *Telephone* **53231 YORKSHIRE**

P381-1B

Ward SPECIAL

TOOLING LAYOUT No. 15





SCREWED RING

Machined all over.

Floor to Floor Time :

1 min. 45 secs.

No. 7 TURRET LATHE

Code Word : **COVHYRO (SP)**

Special Headstock with Spindle having 4⅝" dia. Bore and Fitted with 15" — 3-Jaw Tudor Chuck.

Note :— Time for cutting external and internal threads simultaneously (7 cuts) 25 seconds.

STEEL TUBE

All Tungsten Carbide Cutting Tools.

DESCRIPTION OF OPERATION	Tool position		Spindle Speed R.P.M.	Max. Cutting Speed		Feed	
	Hex. Turret	Cross-slide		Feet per min.	Metres per min.	Cuts per inch	m/m. per rev.
1. Feed tube to stop and close chuck -	1	—	—	—	—	—	—
2. Knee turn 3½" dia., bore, face end and chamfer "A" and "B" - -	2	—	683	627	191	134	·19
3. Back chamfer bore - - -	3	—	683	560	170	Hand	Hand
4. Cut threads 3½" and 3⅛" dias. × 14 t.p.i. Whit. form, right hand (7 cuts) -	—	S.T.1	683	627	191	—	—
5. Part off - - - - - -	—	S.T.2	683	627	191	Hand	Hand

'PRELECTOR' Combination Turret Lathes with Preselective speed-changing.

TURRET LATHES with capacities up to 35 in. swing over bed

1½ in. to 2½ in. 'D-S' DOUBLE-SLIDE' Capstan Lathes for heavier accurate work

Stock Tools, Toolholders, Chucks and Accessories for Capstan and Turret Lathes.

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FITTINGS & ACCESSORIES serving almost every Industry

If we placed an advertisement on every page of this journal we still wouldn't be able to illustrate and specify all the fittings and accessories now incorporated in Enots range of products which include One Shot, Benston and Mechanical Centralised Lubricating Systems, Grease Guns and Nipples, Pressure Oilers, Filters, Coolant Fittings, etc. Control Valves, Air Cylinders, Lubricators, Flow Control, Valves, Solderless Pipe Fittings, Copper, Nylon and Bundy Steel Tube, Flexible Hoses, Fuel Cocks, Filler Caps, Throttle Control Ball Joints, Breathers, Sump Pumps, etc. Fortunately we are able to produce at a moment's notice, the appropriate catalogue adequately covering a customer's particular enquiry. We should like to hear from you.

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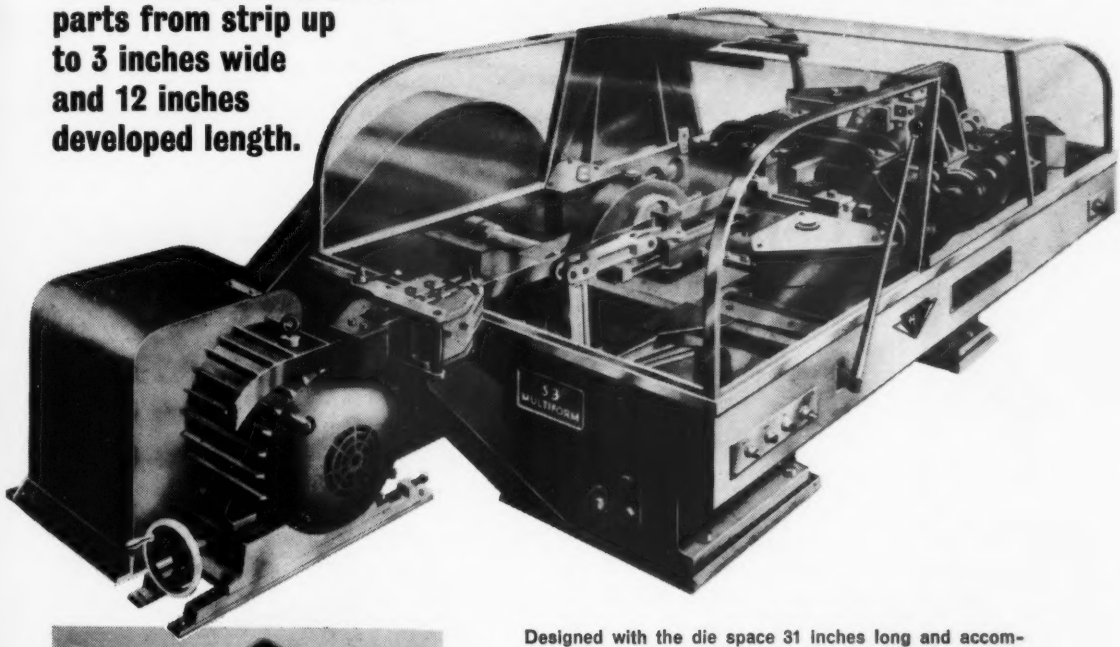
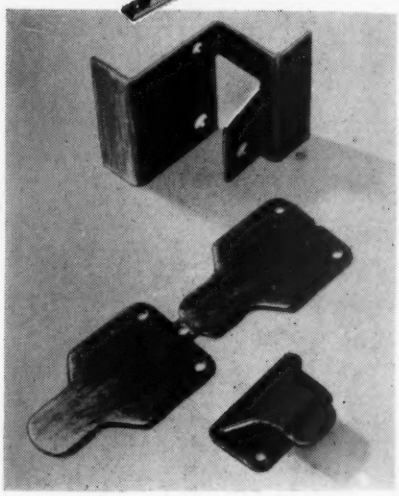
See us at the Engineering, Marine, Welding and Nuclear Energy Exhibition, Stand 43, Inner Row, Grand Hall Gallery, OLYMPIA. April 20—May 4

HEENAN *Multiform*

S3

For forming heavy gauge parts from strip up to 3 inches wide and 12 inches developed length.

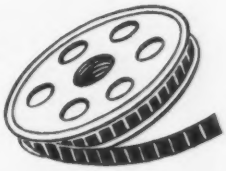




Designed with the die space 31 inches long and accommodating three individually operated diesets, if required, each 10 inches long, the Heenan S.3 Multiform is particularly suitable for the automatic forming of parts requiring substantial presswork, such as piercing, stamping, coining, blanking, embossing and trimming, using progression tooling. Press rams can be operated from front or rear, with 30 tons loading to each ram.

Output rates are variable from 40 to 120 parts per minute. The machine is particularly robust and has been designed to cater for the particularly heavy loads exerted when working on heavy gauge strip.

If fast multi-forming is new to your Company you may freely borrow a 16 m.m. colour film "The Heenan Multiform" which fully describes the technique. Write sole agents below.



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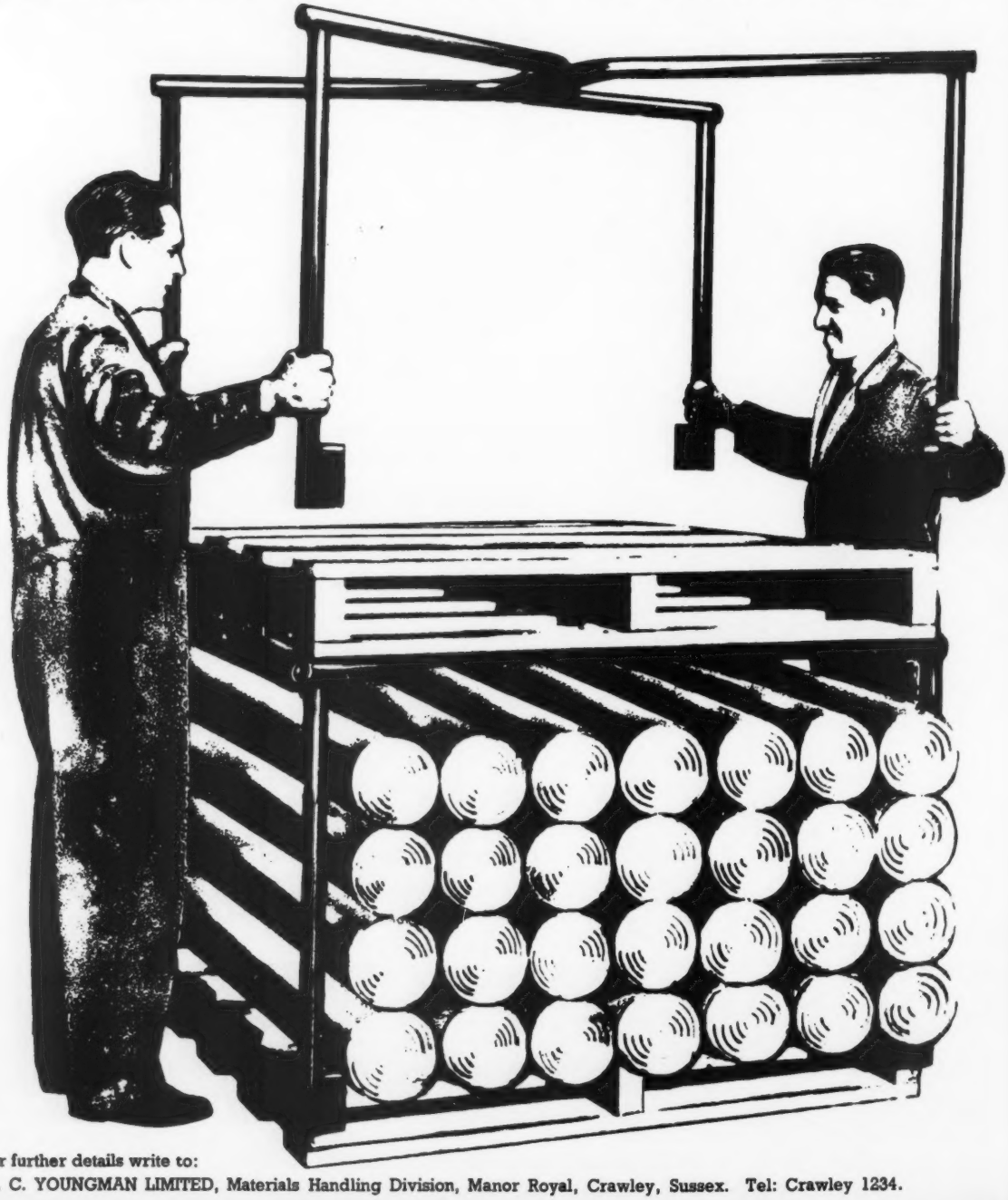

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Note these Gazelle Advantages

Non iron-powder contact type electrode giving maximum ease of use at lower cost · Unequalled de-slagging properties · Excellent weld appearance Minimum cleaning costs · Easy arc striking characteristics · Wide current range for each size of electrode · High travel speeds · Longer run lengths per electrode than with any other Class 2 electrode

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Associated Electrical Industries Ltd

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✳ IMPROVED PITCH SELECTION
✳ INCREASED PITCH ACCURACY
✳ REDUCED HANDLING TIMES
ON

D.S.G.

PRECISION LATHES
WHEN

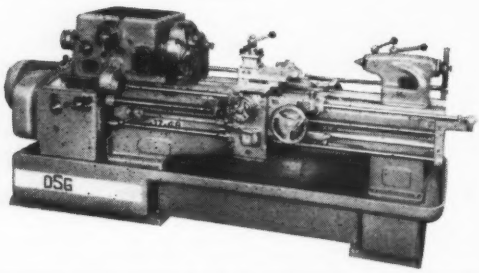
MULTI-START & COARSE PITCH THREADING

Each size of lathe in the D.S.G. range incorporates a totally enclosed screwcutting Gearbox, providing the means for rapidly selecting thread pitches.

The Headstock is fitted with a feed increasing device for coarse pitch threading.

The lathe spindle is fitted with an indexing dial which indicates the precision indexing obtained from a ground divider in the Headstock. This dial is standard equipment on TYPES 13-1 and 17 Toolroom lathes.

WHEN MULTI-START AND COARSE PITCH THREADING, THE COMBINATION OF THESE FEATURES ENSURES THAT ALL THE ABOVE ADVANTAGES ARE OBTAINED.



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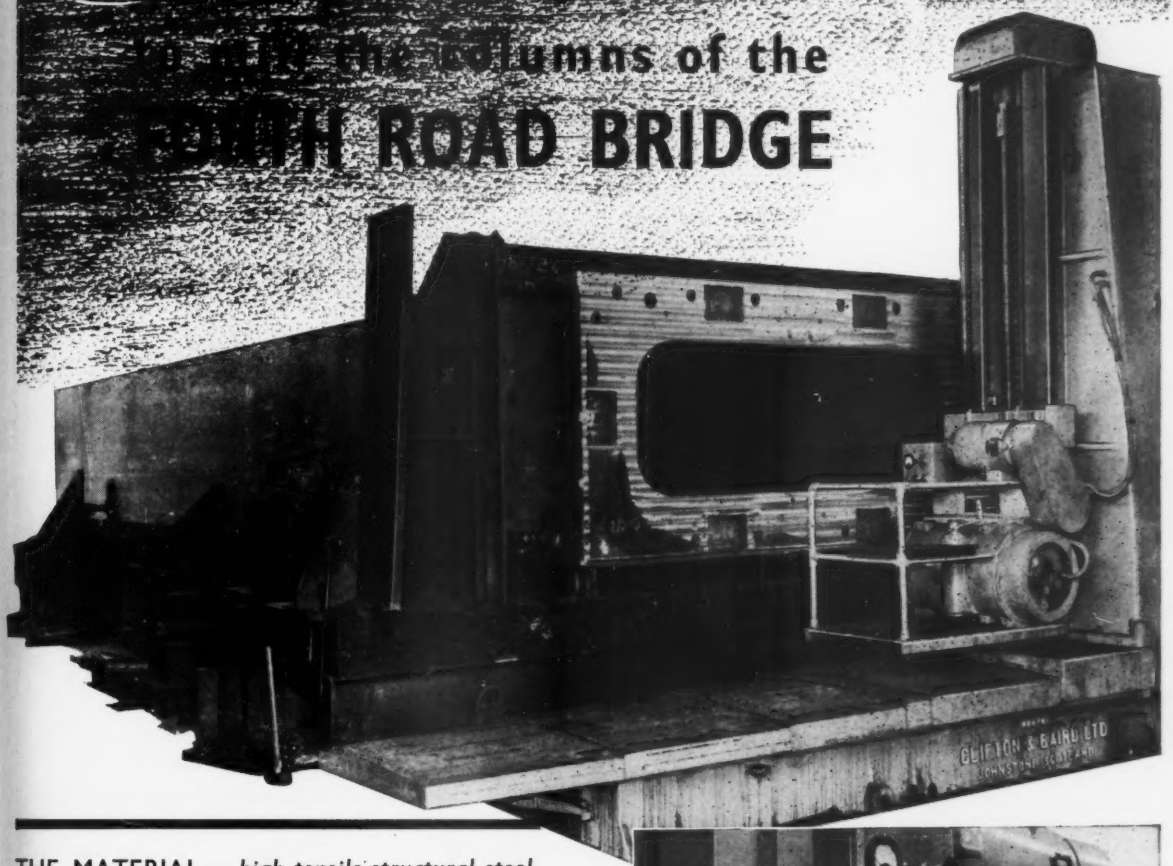
13-30" Swing Engine Lathes
Surfacing and Boring Lathes
Toolroom Lathes

Prolite FUTURMILLS have been chosen

for all the columns of the

FORTH ROAD BRIDGE



THE MATERIAL — *high tensile structural steel.*

COLUMN SIZE — **47 ft. 6 ins.** *long* × **9 ft. 6 ins.** × **5 ft.**

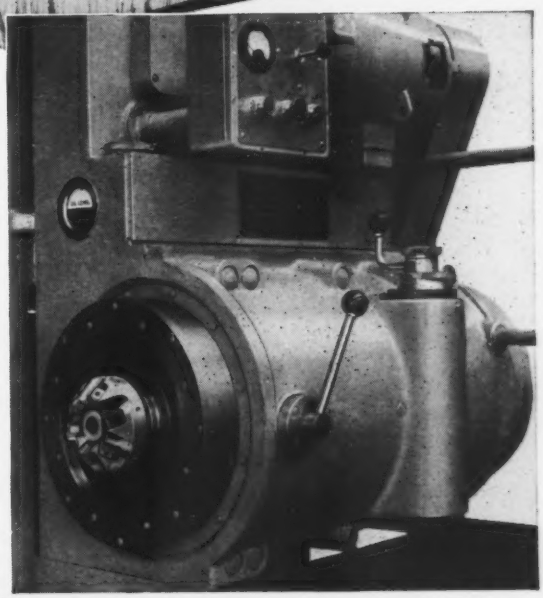
THE MACHINED AREA — **9 ft. 6 ins.** × **5 ft.**

THE DEPTH OF CUT — *approximate* **¼ in.**

using a 3 in. dia. Type FM45 FUTURMILL

FEED RATE — **60 ins.**

using 'PROLITE' GRADE 20K



The Prolite-Futurmill FM45 is a cutter of unique design using throw-away blades which give improved performance, lower production costs, and longer cutter life. Our engineers are available at any time for consultation and demonstration in your works.

Photographs by courtesy of Sir William Arroll & Co Ltd. and Clifton & Baird Ltd., designers and builders of the machine.

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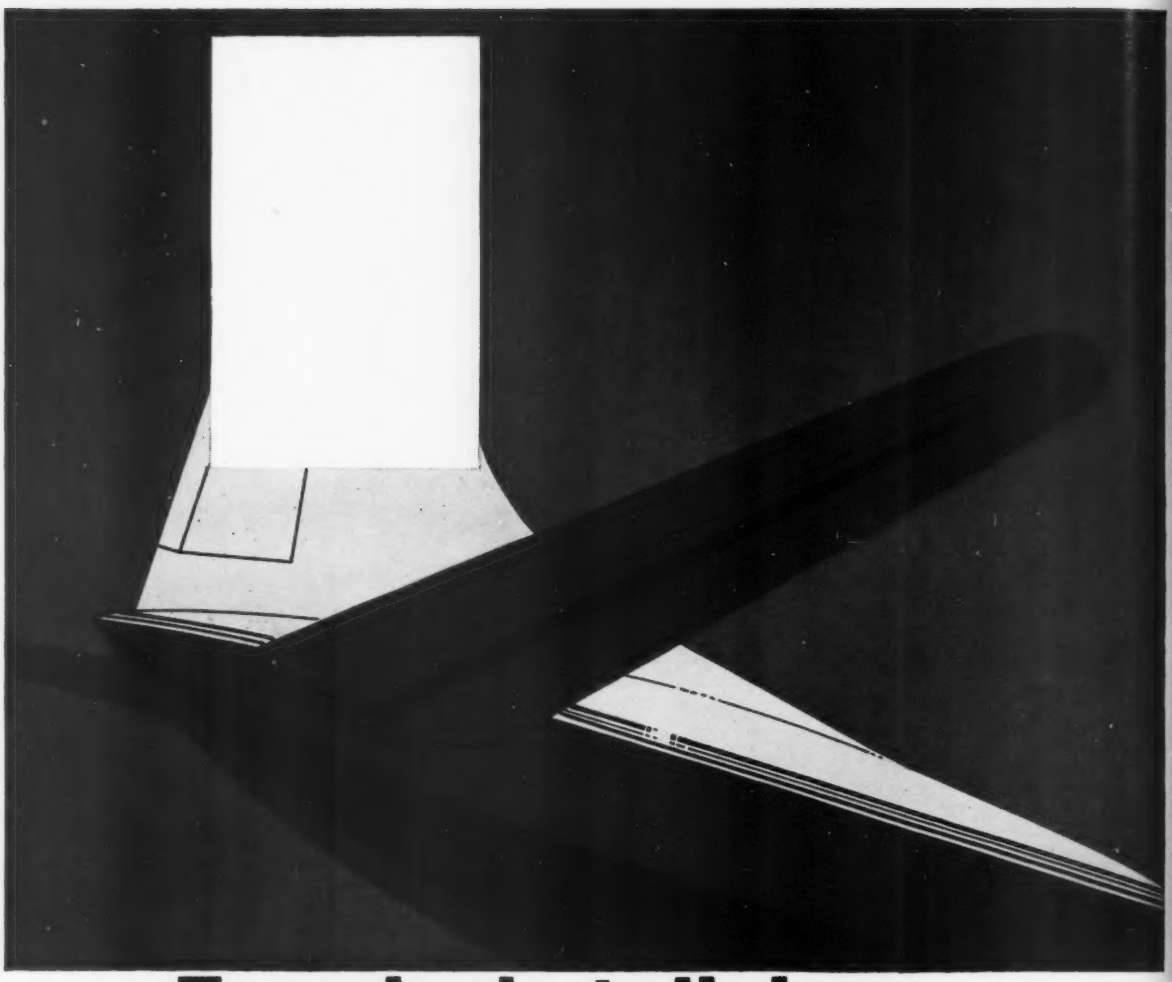
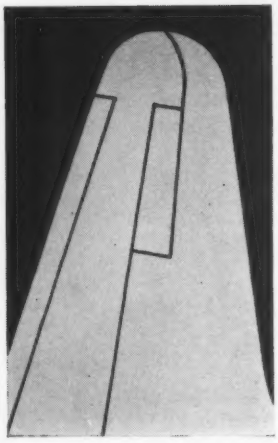


Tuesday's tailplane



There is no doubt that the tailplane will be there on Tuesday – or that every other part and sub-assembly will be available on the scheduled date.
• The Bradma Production Control System is the manufacturer's complete assurance.

It is suitable for every type of organisation – large or small – whether manufacturing turbo-jets or children's bicycles.
• The Bradma Production Control System means improved efficiency.

In every Industry, manufacturing delays are possibly the most serious and costly hazard likely to be encountered.
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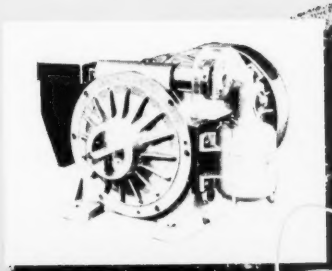
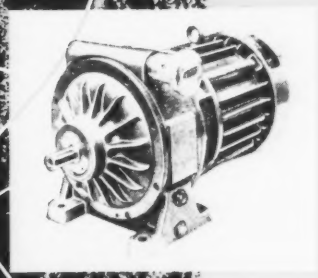
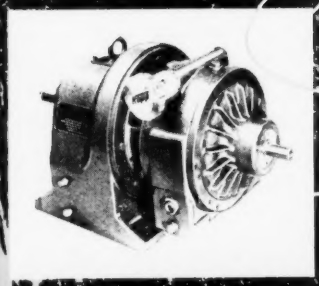
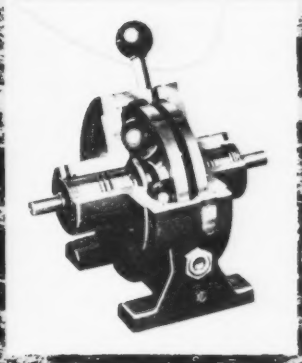






controlled
variable
speed



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- 9 to 1 stepless speed variation.
- Flange mounted motors (when required).
- Flange mounted Reduction Gears for low output speeds.
- Exceptionally light, sensitive, and accurate control of speed settings by handwheel, pneumatic, mechanical or electrical remote control.

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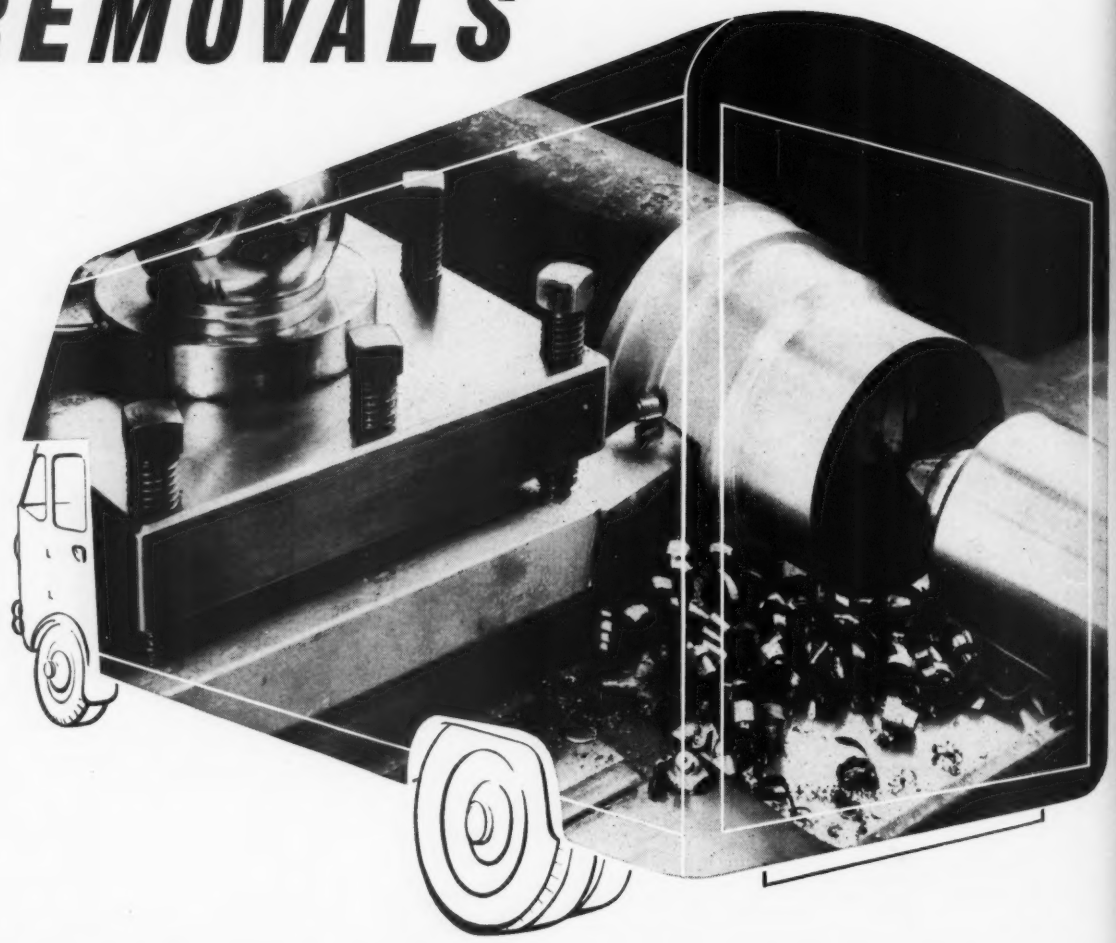

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Five per cent of Vanadium, in addition to Cobalt, makes Vanleda one of the most valuable steels in the modern machine shop. Possessed of a very high resistance to abrasion its use for single point tools on high speed automatic lathes has met with outstanding success. Here it has proved to be superior to the more conventional cobalt high speed steels. Nevertheless it is but one of the famous range of Firth Brown high speed steels to which section seven of the Firth Brown catalogue is a complete guide. A copy of section seven is yours for the asking.

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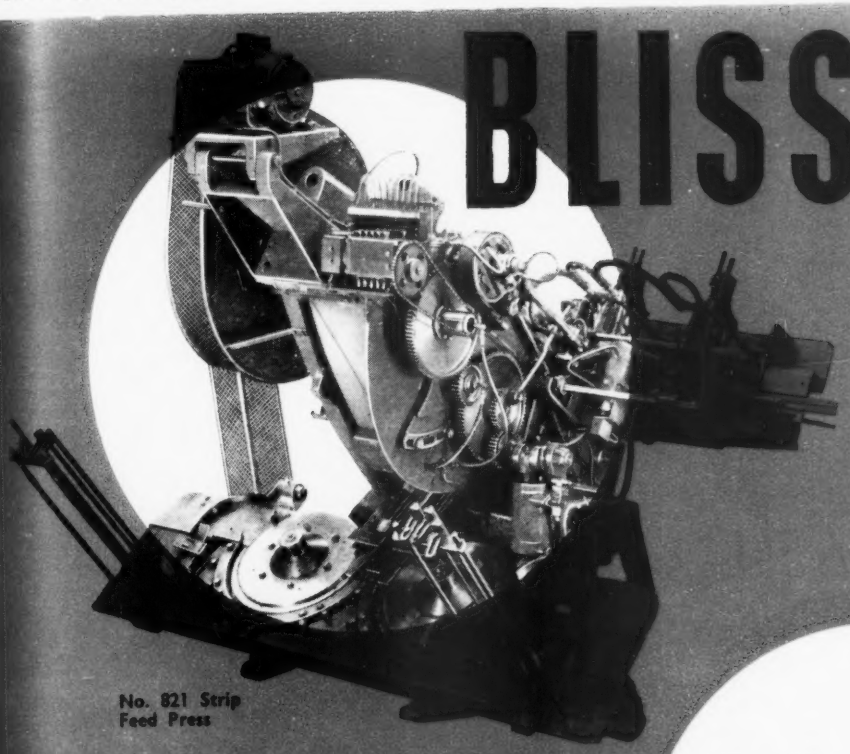
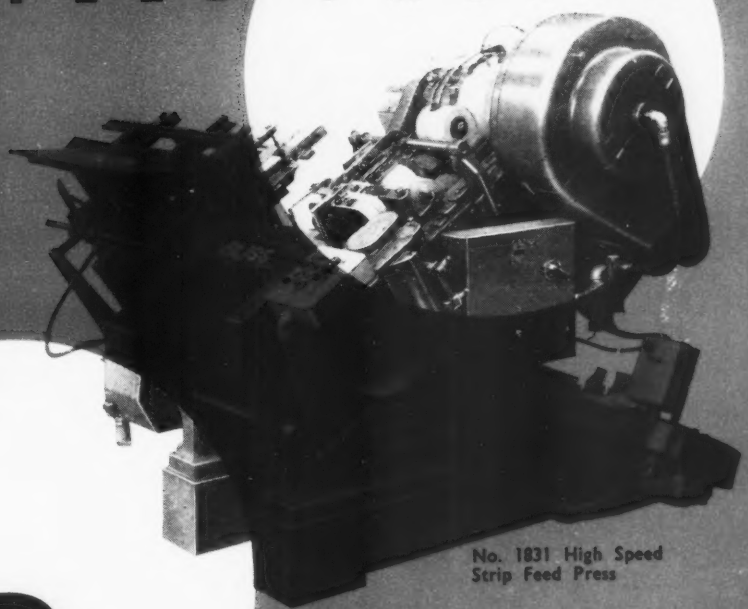


No. 821 Strip Feed Press

STRIP FEED PRESSES

Specially designed for fast economical production of can ends, bottle closures and similar stampings, Bliss Strip Feed Presses are available in four models covering speeds up to 300 s.p.m. Send your samples and details of hourly output required and let Bliss submit their recommendations for the press most suited to your needs.



No. 1831 High Speed Strip Feed Press

BLISS since 1857

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gives more than elbow room!

This rugged development
does more than save the operator's time
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- ★ It allows hands to be free for guiding work.
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- ★ Replaceable switching unit. Contact arrangement: single pole, double throw or double break. Electrical rating: 20 amps 240v AC; 1½ HP, 230v AC; ½ amp 250v DC or governed by basic switch rating.
- ★ Treadle operating position can be adjusted.
- ★ Cast iron construction, completely sealed.

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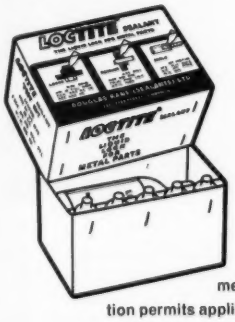
This is LOCTITE SEALANT

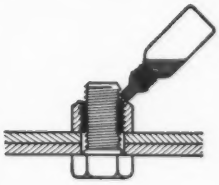
The Sensational Liquid Lock for Metal Parts

LOCTITE SEALANT supersedes all conventional methods of locking nuts, bolts, studs, set screws, adjusting screws—anything which may vibrate loose. It dispenses with lock nuts and other mechanical locking devices and methods—with outstanding cost savings. **LOCTITE SEALANT**, the new liquid plastic, penetrates between threads or closely fitting metal parts and hardens automatically inside the joint to give a permanent lock and seal to the joint, superior to any mechanical locking devices. **LOCTITE** treated parts can *NEVER* work loose, yet can be removed with ordinary tools.



THE LOCTITE TEST KIT

contains five grades of Loctite for experimental work. Grade selection permits application of predetermined locking torque on any size fastener.



LOCKS

Makes any threaded part self-locking

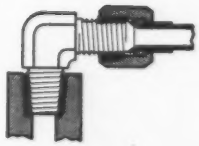
★ prevents breakdowns caused by loose bolts, nuts, studs and screws

RETAINS

Makes bearing replacement easy

★ retains bearings without press fit

★ eliminates reboring, sleeves, shims, and weld metal build-up



SEALS

Prevents leaks in high-pressure fluid lines

★ completely fills joints with tough plastic

★ resists heat, cold, fuels, oil, water, solvents, all hydraulic fluids

★ contains no solid particles to foul valves

Take the first cost and trouble saving step by writing *NOW* for the Technical Report on Loctite Sealant.

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AP118

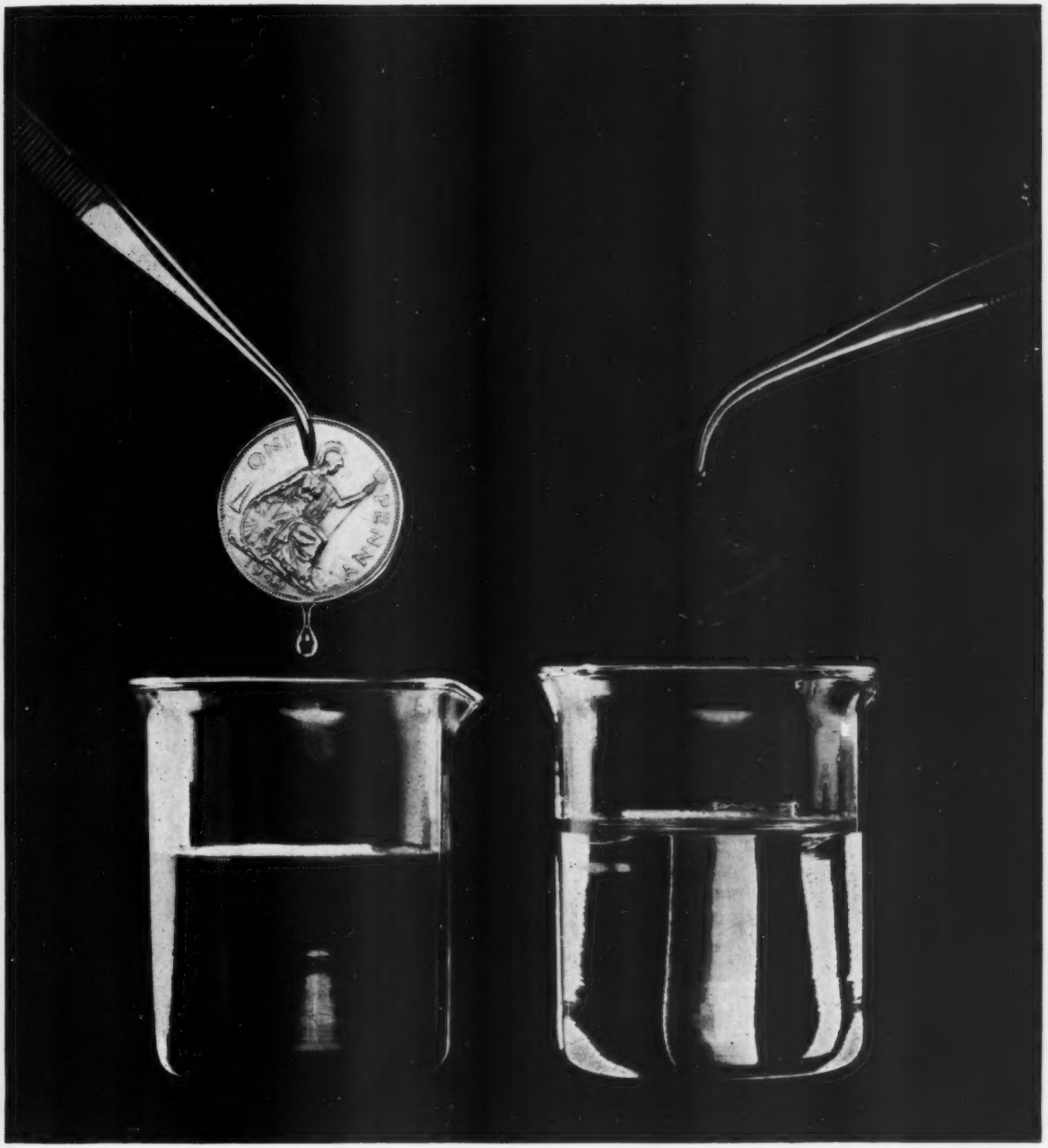
Shell achievement

One of Shell's recent achievements in Industrial Lubrication has been to reduce the risk of skin trouble for machine operators. Until the new Shell Dromus range, most modern soluble cutting oils contained phenolic compounds, which can cause skin irritation. They were used as coupling agents between the actual oil and the emulsifier. On high-speed machines, especially, the water evaporates and the emulsion concentrates. And that's when the trouble can start. Shell scientists found a better coupling agent, and made it work. And now, at no extra cost, management can reduce working risks for their staff. *Write for the book, 'Selecting Your Cutting Oils', to Shell-Mex House, London, W.C.2.*

SHELL

SHELL INDUSTRIAL OILS

Shell demonstration



Two clean, bright pennies are placed in beakers of oil, of equal performance level, one Shell Garia Oil 21, the other a conventional cutting oil containing sulphurised additives. After three hours at room temperature one penny is still bright and stain-free, the other heavily stained with black copper sulphide. The bright penny is from the beaker containing Shell Garia Oil 21, the blackened one from that containing the conventional oil. While these were just pennies they could have been bronze bushes in your machine tools—stained in less than half a shift. Sulphur is essential in heavy-duty cutting oils. Special additives in Shell Cutting Oils protect your machine tools and yet allow the sulphur to do its job. *Write for the book "Selecting Your Cutting Oils" to Lubricants Department, Shell-Mex House, London, W.C.2.*

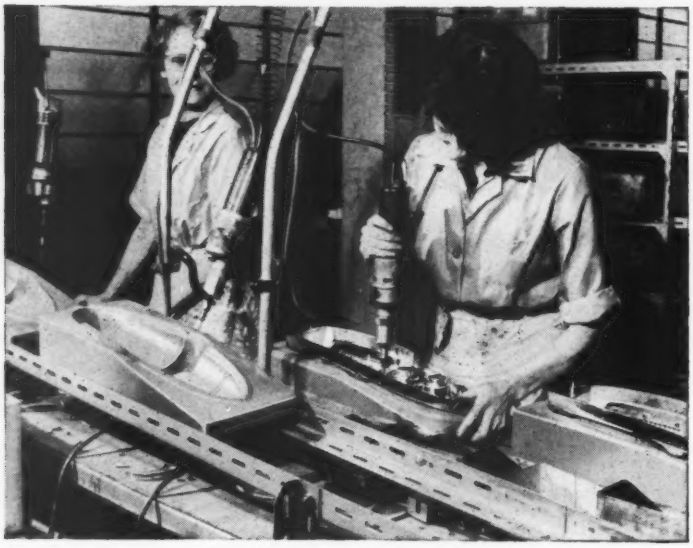
DROMUS . . . PELLA . . . MACRON . . . GARIA

SHELL

SHELL CUTTING OILS

ARALDITE
CUTS TOOL ROOM COSTS

Araldite resins enable manufacturers to produce, speedily and at low cost, assembly jigs which are replicas of original patterns. These jigs can be cast at room temperature and as there is negligible shrinkage on setting, they possess high dimensional accuracy. Araldite is available in forms which will provide any required degree of hardness, and a resilient surface is often used to prevent damage to highly finished products. Araldite jigs are tough, durable and require no maintenance, either in use or in storage. Also, they are much lighter and easier to handle than their metal counterparts. Araldite can probably save you money on your own assembly lines. Let us send you our booklet "Araldite Resins for Tooling".



Araldite faced jigs are used by Butlers Ltd, Birmingham, in the assembly of combined tail and stop lamp shells for cars.

Araldite epoxy resins are used—

For casting high grade solid electrical insulation

for impregnating, potting or sealing electrical windings and components

for producing glass fibre laminates

for producing patterns, models, jigs and tools

as fillers for sheet metal work

as protective coatings for metal, wood and ceramic surfaces

for bonding metals, ceramics, etc.

Araldite *epoxy resins*

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AP590

The Lincoln SPRITE CO_2 Welding Unit, showing the Remote Amperage Control Box for 'on the spot' control of welding current and the Lincoln K-W1 CO_2 Hand Welding Gun.

SPRITE CO_2 WELDING

- is simple to operate
- is exceptionally versatile
- is up to 50% faster than older methods of manual welding
- eliminates electrode changes, wasteful stub ends—gives maximum welding time
- solves de-slagging problems—as the arc is shrouded with CO_2 gas, little or no slag is formed on the weld, thus saving clean-up time.

In short, SPRITE CO_2 Welding means faster, better welding at lowest cost!

Look Spritely—get more information *now* from:

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A MEMBER OF THE GKN GROUP OF COMPANIES

No need for additional machines and extra floor space

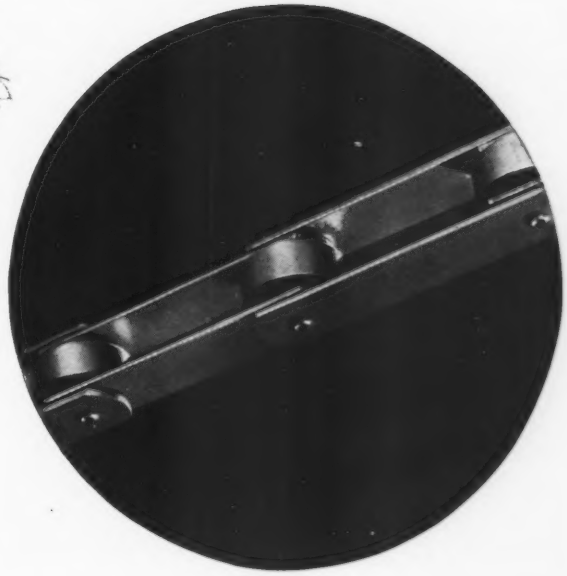
DIMENSION INDICATORS

* Reduce stoppages for measurement after each cut.
* Increase machine utilisation and output.
* Reduce setting errors.
* Direct readings of workpiece dimensions give greater speed and accuracy.

Full technical details on request

English Numbering Machines Ltd.

Dept. 3K · QUEENSWAY · ENFIELD · MIDDX · HOWard 2611 (5 lines) · Grams: Numgravco, Enfield



I carry anything

Heavy or light loads . . . bulky packages or small units.

Just as everything is within the scope of the elephant, so it is with Renold conveyor chains—but Renold chains carry everything faster, smoother and safer under all conditions.

Write for Catalogue Ref. 120/19 giving full details of

RENOLD STOCK CONVEYOR CHAINS

WITH ATTACHMENTS FOR ALL DUTIES

RENOLD

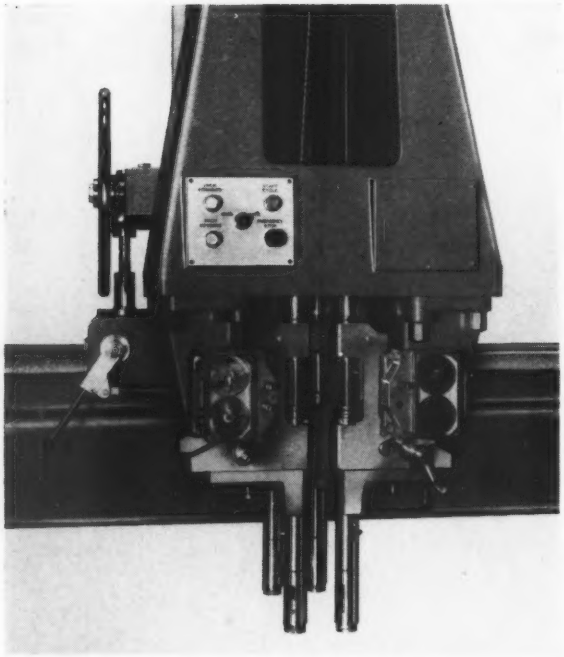
RENOLD CHAINS LIMITED • MANCHESTER

Multi-spindle Machines

Speed up holemaking for Structural Engineers

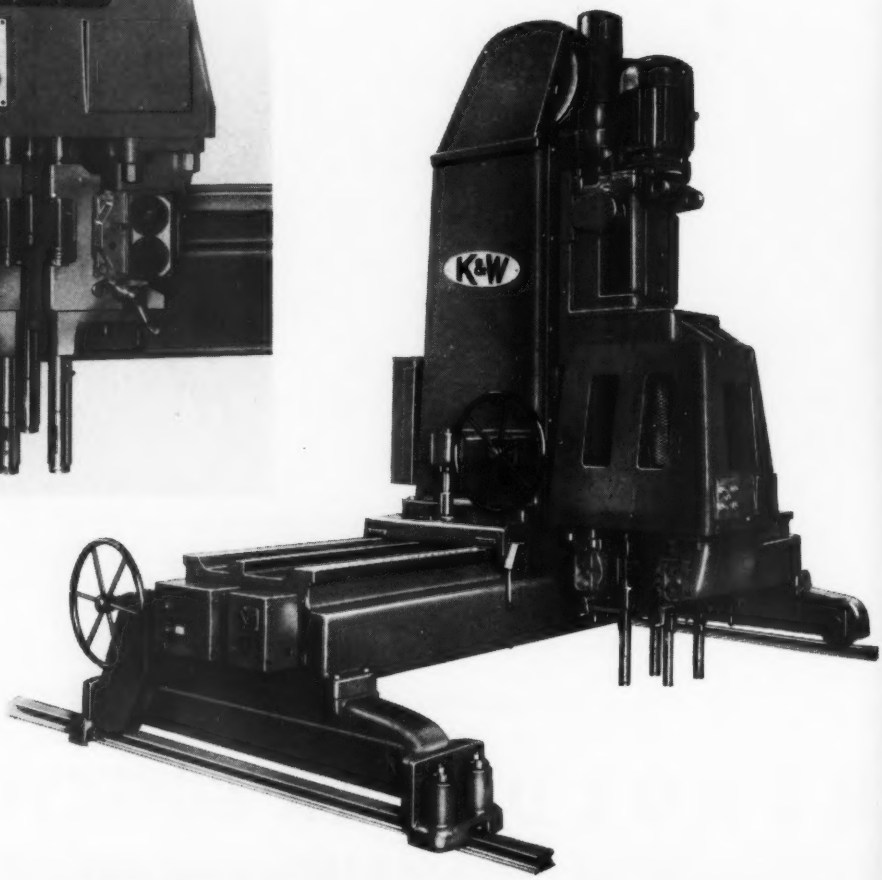
These machines can be supplied with single or duplex heads. Provision is made for aligning the crossrail at right angles to the track and the four spindles of the multi-head can be quickly adjusted to requirements for drilling position relative to each other.

Machines of this type have been supplied recently to an American Structural Engineering Works and the advantages in cutting down machining time on structural members can be readily visualised. Write today for full details.



On the left is a close-up of the drilling head showing dials for setting position of each spindle.

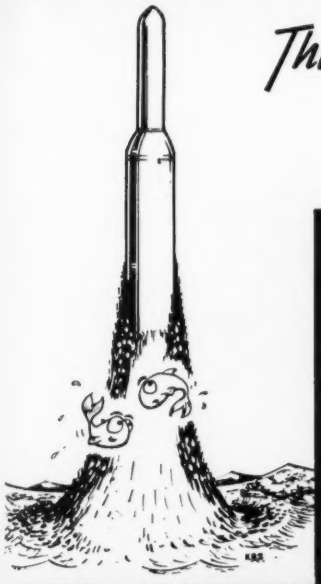
Below is a view of the complete machine with single head.



KITCHEN & WADE LTD. *Member of the Asquith Machine Tool Corporation*

ARUNDEL STREET, HALIFAX, ENGLAND *Telegrams : 'KAW, Halifax'. Telephone : Halifax 67744 (3 lines)*

KW55



This is nothing to what goes on inside a

BULLOWS

NOPUMP SPRAY BOOTH

In this new type of Water-Wash Spray Booth the exhaust air travels at very high velocity over the water surface entraining water. The air/water mixture, moving through controlled changes of direction, provides the scrubbing action.

NO PUMP

NO FILTERS

NO PIPES

NO NOZZLES

WASHING MACHINES BEING SPRAYED IN NOPUMP BOOTH AT ADA (HALIFAX) LTD.

CUTS MAINTENANCE BY 90%

Longer time between clean-outs

Residues completely broken down and easily handled

Lack of adhesion of deposits

Smooth, easily cleaned surfaces

Low first cost due to simplicity

Occupies minimum space

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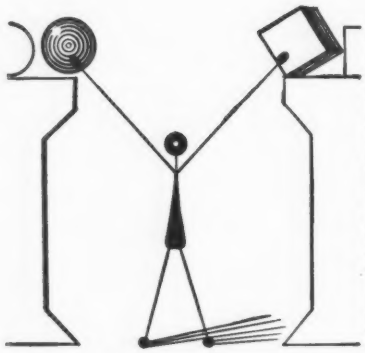
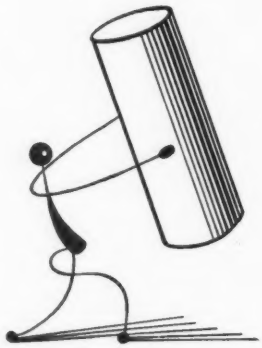
BULLOWS (AUST.) PTY. LTD. ETHEL AVENUE, BROOKVALE, SYDNEY, AUSTRALIA

Hymatic Automation

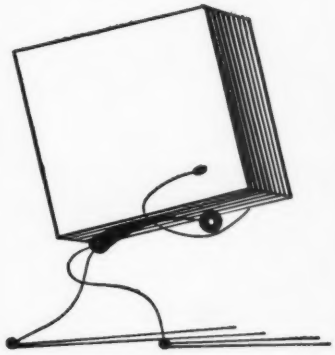
IS THE NAME FOR MACHINES THAT



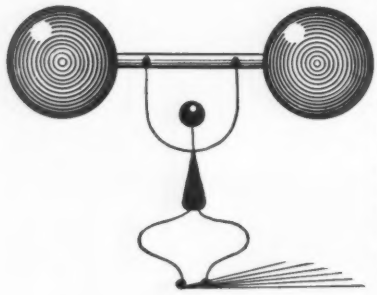
...reach...



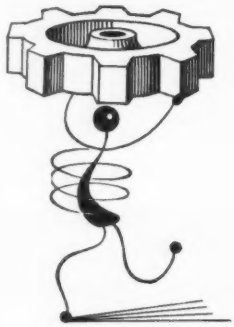
...grasp...



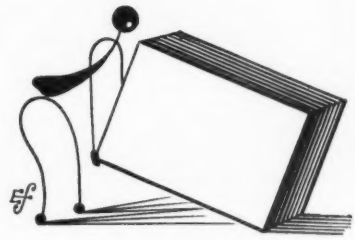
...carry...



...lift...



...turn...



...tilt...

...roll, dislodge, clean, sort, shelve, clamp and feed parts. Hymatic Automation is thus invaluable in the automatic and selective transfer of parts from one process to the next, from conveyor to conveyor; in unloading one machine and loading the next; or in quick clamping to hold parts during machining. All designs of Hymatic Automation are made for specific tasks but are readily adaptable to others. Hymatic Automation covers the whole problem—the design of the circuit—the machine—the means of control.

Hymatic Automation, therefore, has a place in your programme of productivity improvement.

Perhaps in your Works, too, there are jobs where it is possible for people to burn or cut themselves, strain or crush themselves, lose fingers or even a hand; or perhaps there are jobs for which you just cannot find people.

***In all events* CONSULT**

Hymatic Automation

THE HYMATIC ENGINEERING CO. LTD · DEPT. HA.84 · REDDITCH · WORCS.

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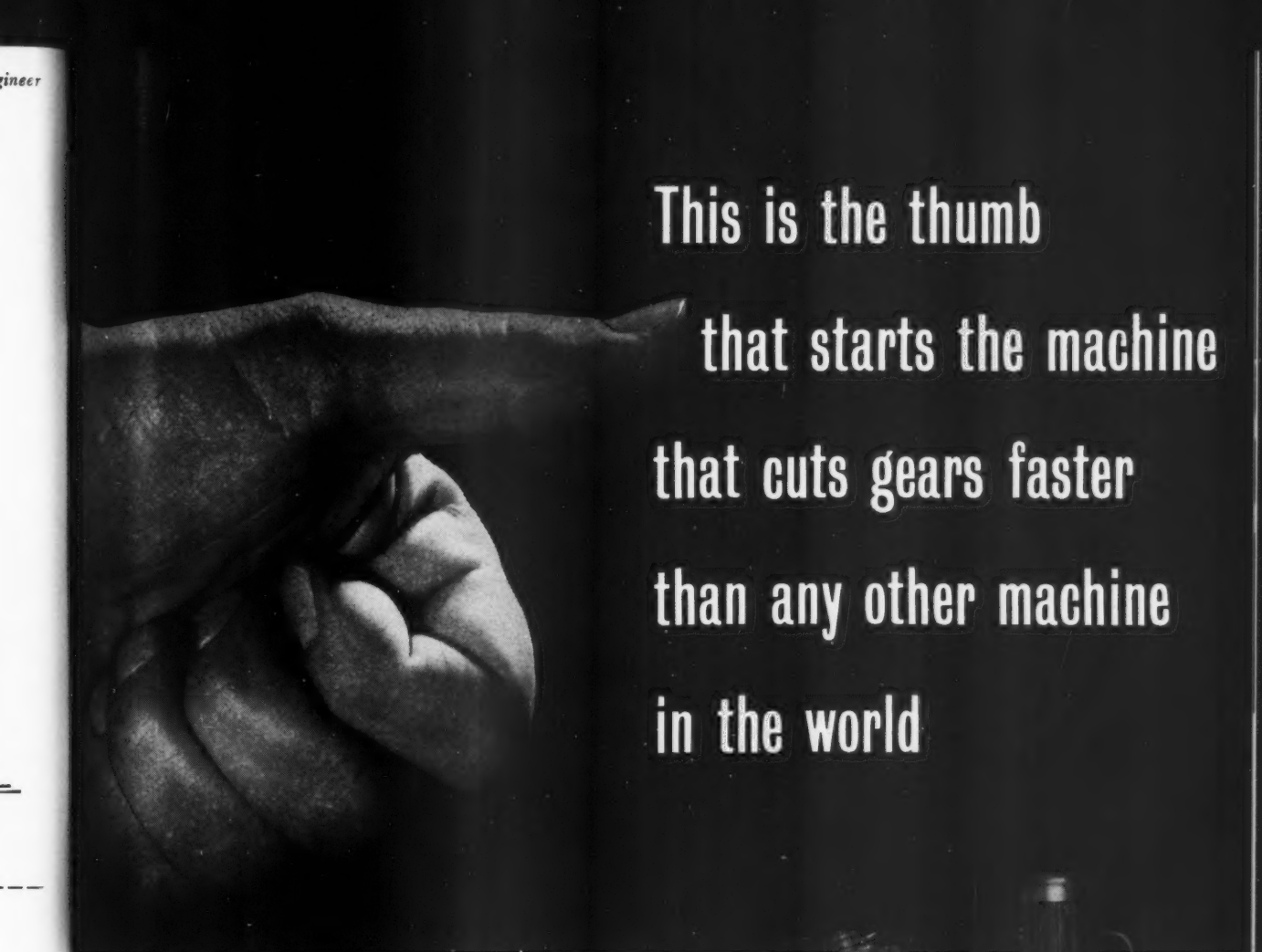

This is the thumb that starts the machine that cuts gears faster than any other machine in the world

Whose thumb is it? It could be anyone's. The ownership of the thumb is unimportant. It's the ownership of the machine that counts. For the machine is a Hydrax — the world's most advanced gear hobber. Anyone who owns a Hydrax cuts gears at an astonishing speed — automatically — accurately. Hydrax hobbing means multi-spindle production from a single-spindle machine. If you really want to get hobbing, you'll want information about the Hydrax range. We'll be glad to send you literature.

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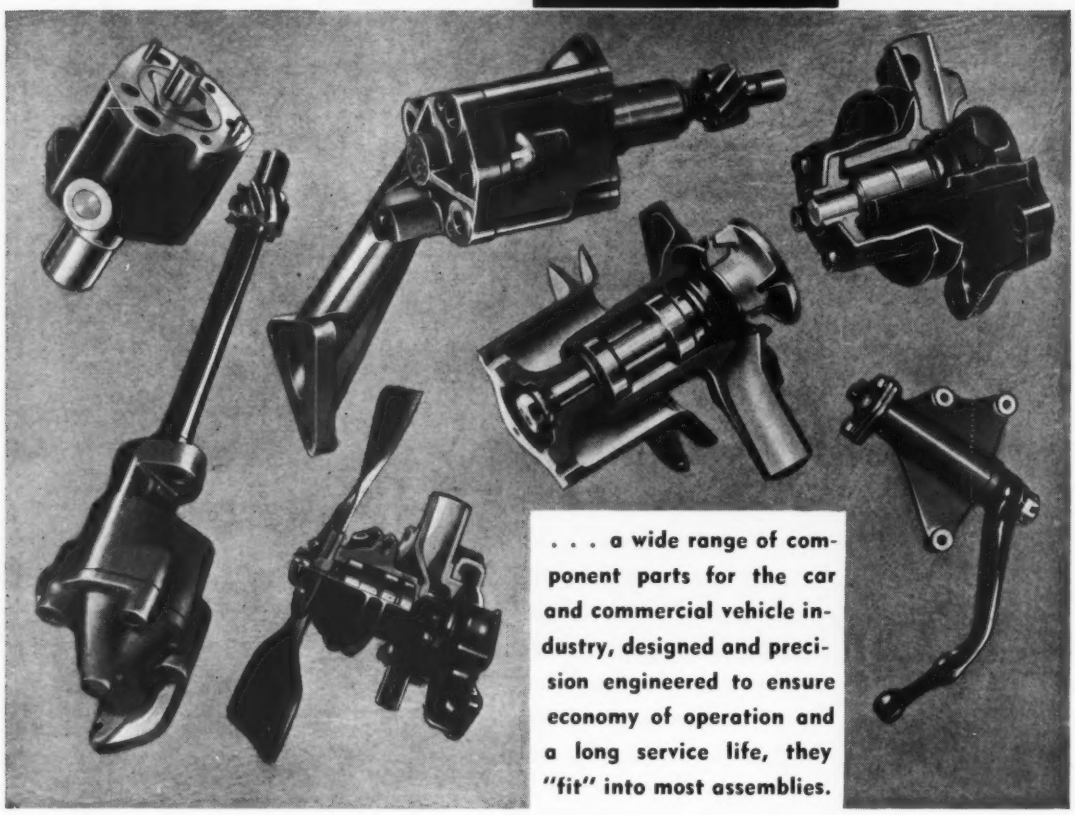
CONCENTRIC COMPONENTS



. . . a wide range of component parts for the car and commercial vehicle industry, designed and precision engineered to ensure economy of operation and a long service life, they "fit" into most assemblies.

Concentric, specialists in the design and manufacture of Oil and Water Pumps have achieved a new high standard of performance and production in this field.

Oil Pumps, Water Pumps, Steering Idlers, Clutch Plates, Gear Change Mechanisms, Bearing Boxes, Brake Drums, Brake Discs, Push Rods, Ball Pins, Shackle Plates, Axle and Hub Assemblies, Thrust Plates and Assemblies, Machined Components of all kinds.

FIT INTO *your* SCHEME OF THINGS

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Electrical Aids in Industry

Data Sheet **No.17**

Canteen Catering

As in every other industry, the main factors governing the economics of the catering business are: quality of product, cost of production, and well-being of workpeople. Electricity measures up well to these three essential factors.

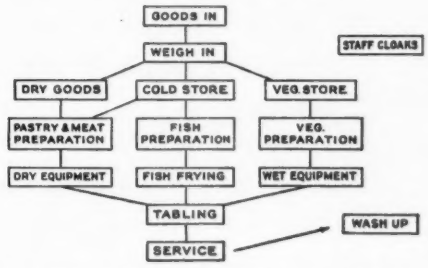
The outstanding virtue of electricity is better cooking, particularly in roasting and pastry ovens where high quality is more easily maintained than in ovens using other forms of heat. The cost of production varies somewhat with the type of food and the size of the establishment, but is usually between $\frac{1}{2}$ and $\frac{3}{4}$ of a unit of electricity per meal. Cleanliness of electric cooking is axiomatic and provides better working conditions for the staff.

The actual size of the kitchen is influenced greatly by its shape and by the number of people catered for, but a rough guide is as follows:

KITCHEN TO DEAL WITH	SIZE
up to 100 persons	5-6 sq. ft. per person
100-250 persons	4-5 sq. ft. per person
250-1000 persons	3-4 sq. ft. per person
over 1000 persons	3 sq. ft. per person

Design

Where the kitchen is designed from the start for the full use of electricity, planning is simplified as the equipment can be placed where it is required without reference to the need for flues.

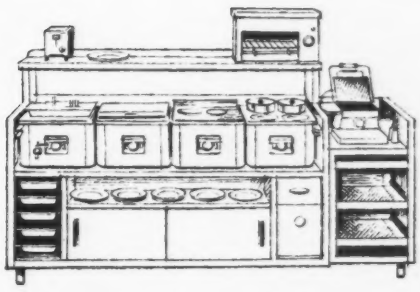


If an existing kitchen is already using other types of cooking equipment, however, electrical equipment can still be introduced item by item to bring increasing benefits.

Quick-service Equipment

The popularity of the quick-service establishment where the food is cooked at the service counter in the full view of the customer is steadily growing, and this type of catering can readily be provided in the canteen by the installation of a Back Bar cooking unit, installed behind a section of the service counter.

The popularity of the mid-day joint and two vegetables is on the wane and the really up-to-date

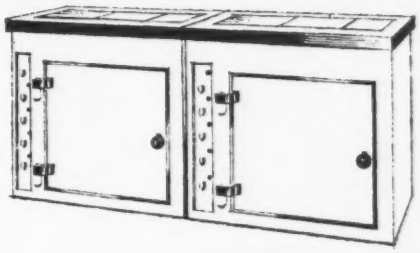


canteen should provide the welcome alternative of fresh food cooked on the spot.

Electric Catering Equipment

Electric catering equipment covers every single kitchen activity and some of the appliances in common use are:

COOKING. Ranges, boiling tables, steaming, roasting and pastry ovens, vegetable boilers, fryers, griller/toasters.



SERVICE AND WASHING-UP EQUIPMENT. Bains-marie, hot cupboards, tea and coffee machines, washing-up machines for the larger kitchen and sterilising sinks for the smaller, refrigerated cold-service counter and display cabinets, soda fountains.

PREPARATION. Mixing machines with attachments for chopping and mincing etc., potato peeler, slicing machine.

QUICK-SERVICE EQUIPMENT. Infra-red (contact) grill, automatic toaster, griddle plate, automatic fryer, boiling plates, soup heaters, etc., and, of course, the indispensable refrigerator.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Excellent reference books on the industrial and commercial uses of electricity are available—" Electric Commercial Catering Handbook " (5/-, or 5/6 post free) is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including commercial catering. Ask for a catalogue.

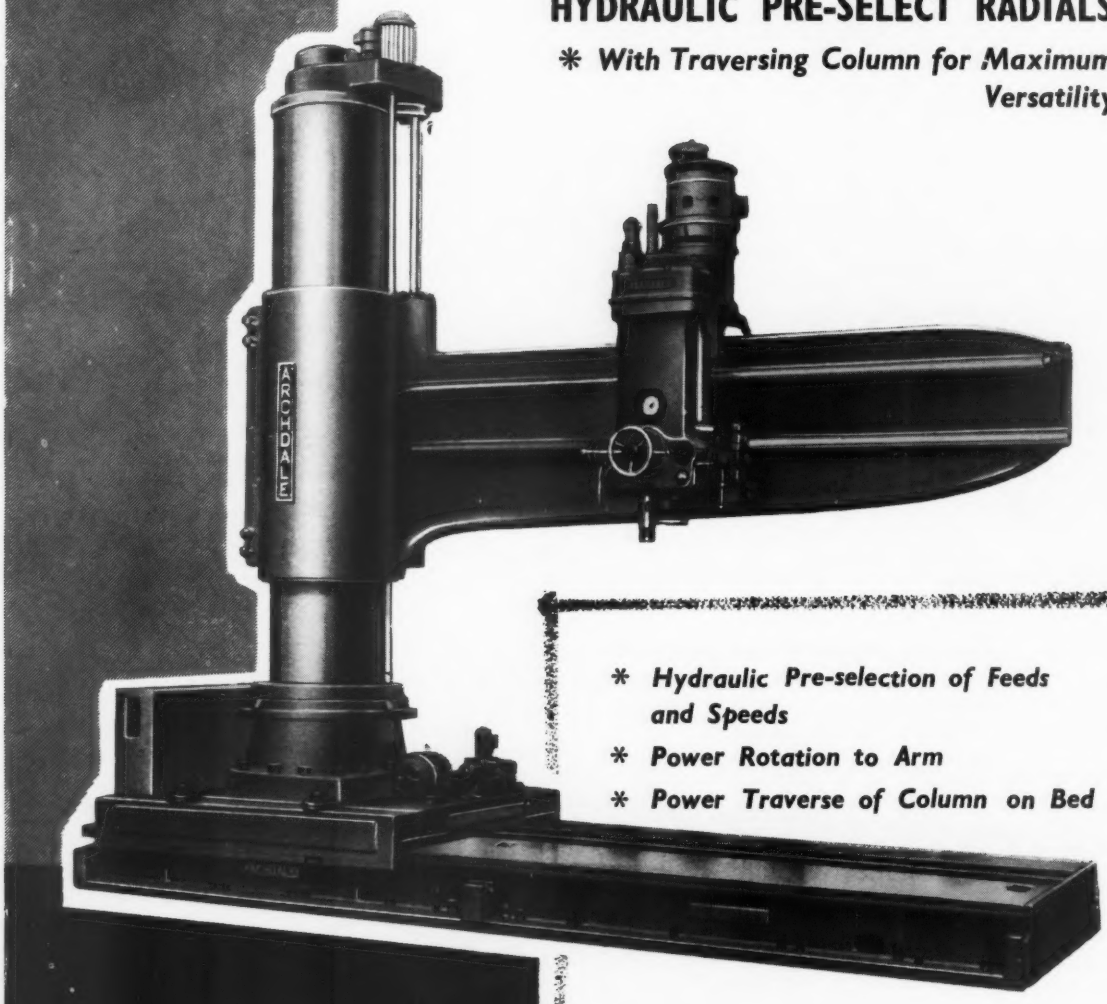
12799

CUT HERE

ARCHDALE

HYDRAULIC PRE-SELECT RADIALS

**** With Traversing Column for Maximum Versatility***



- ***Hydraulic Pre-selection of Feeds and Speeds***
- ***Power Rotation to Arm***
- ***Power Traverse of Column on Bed***

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STAVELEY GROUP

With 14 ft. spindle radius, a drilling capacity of 3½ in. dia., in mild steel and hydraulic pre-selection of feeds and speeds, the versatility of this machine is further increased by its moving column which traverses the length of the bed on plastic faced slide ways. 24 spindle speeds, between 7 and 1,450 r.p.m., 18 feeds 0.040 - 0.002 in./rev. Maximum distance, spindle nose to table 118 in., minimum 28 in. Full details in literature available on application.

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Spiral Bevel Gear Generators

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1. Ring gear and pinion roughed and finished in one single operation, thanks to combined plunge-cut and generating method.

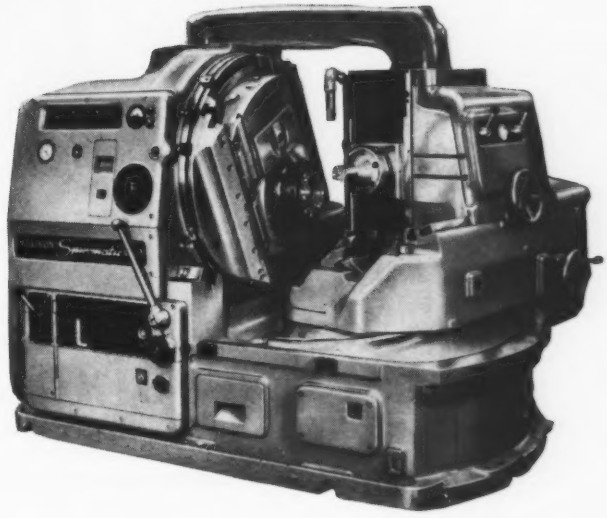
2. Highly accurate and concentric teeth, because all tooth flanks are cut in one operation — with continuous indexing.

3. Uniform tooth height, which means theoretically accurate teeth and easy computing of all gear drives, no matter whether with intersecting or offset axis.

4. Maximum flexibility of the SPIROMATICS for profile and tooth bearing modification.

5. Easy cutter change. Cutters can be adjusted off the machine.

6. Quick and easy setting and re-tooling; efficient for small batches too.



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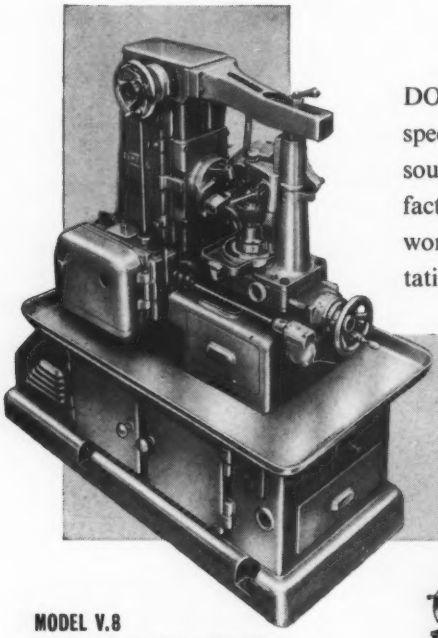
HOBBING

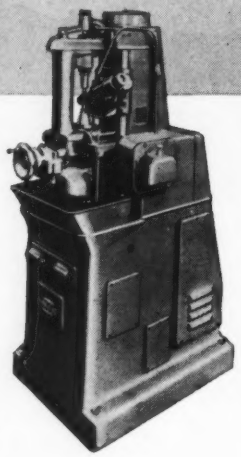
–it pays to investigate

BRITISH-BUILT DOWDING

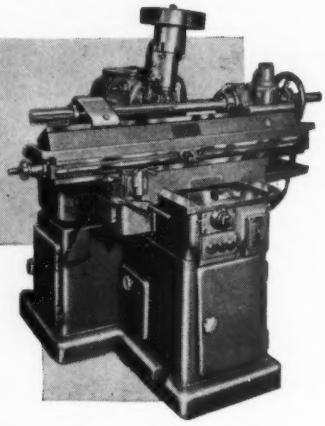
DOWDING Hobbers have been developed by gear specialists: their accuracy and economy are the result of sound basic design coupled with craftsmanship in manufacture. They are to be found in leading engineering workshops throughout the world, earning a high reputation for their accuracy and dependability.



MODEL V.8
UNIVERSAL HOBBING MACHINE
Accurate, versatile, economical. With built-in differential. For spurs, helicals, wormwheels, and worms. Tangential feed and cam operated plunge feed are optional extras. Maximum dia. 8″, 7″ Face. 12 D.P.



MODEL V.4
UNIVERSAL HOBBING MACHINE
Accurate, rigid, and versatile. With built-in differential. For the smaller spurs, helicals, worm wheels, and worms used in light engineering and instrument work. Tangential feed is also available.
Up to 4″ Diameter, 4″ face, 20 D.P.



MODEL H.7
HORIZONTAL HOBBING MACHINE
Powerful and rigid. With built-in differential. For long splines and gears integral with long shafts, and parallel and taper serrations. Alternative heavy duty or high helix angle hob heads. Maximum dia. 7″. Hobbing length 18″. 8 D.P.

Ask us to send our new illustrated Hobbing brochure PE/128

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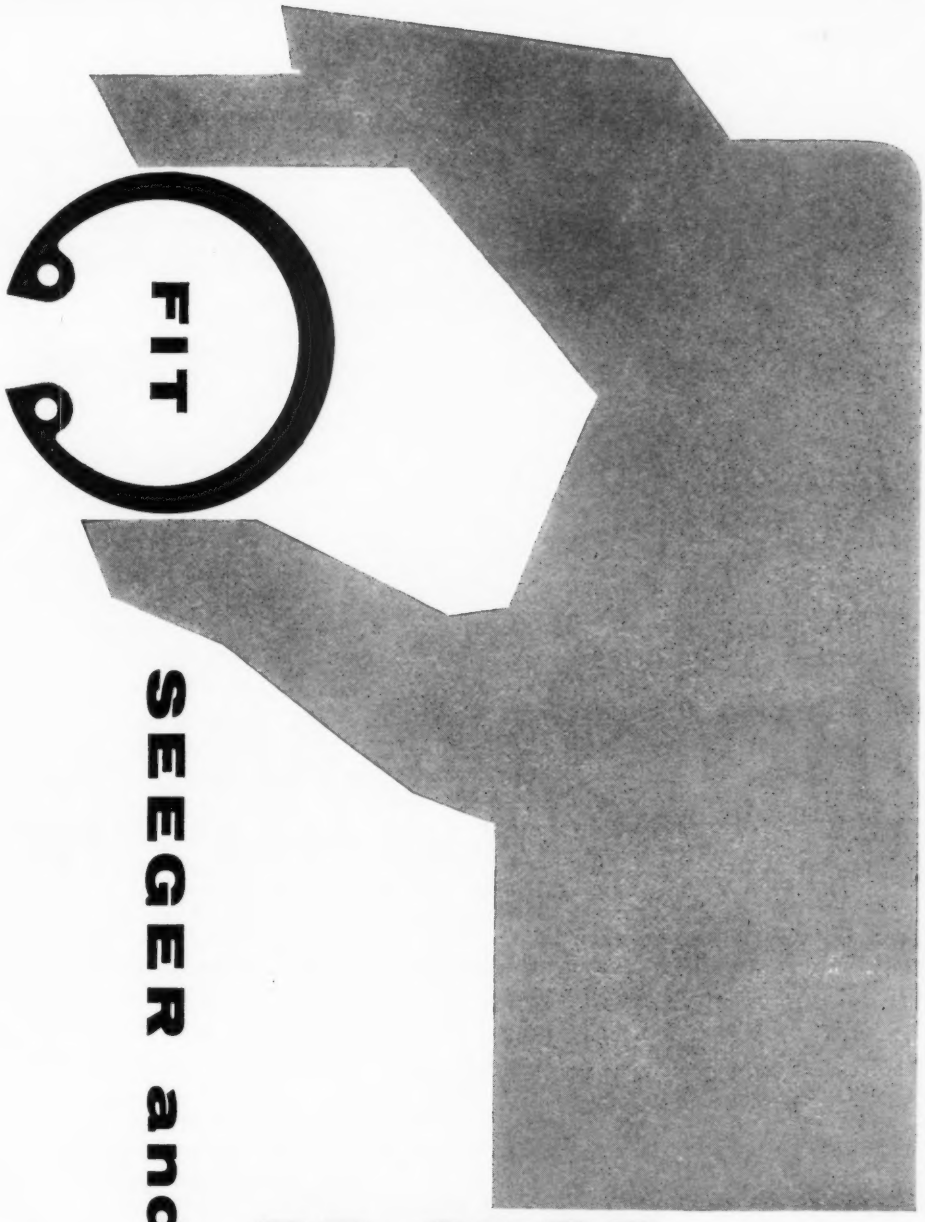

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The Green, Twickenham, Middlesex
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Telegrams: Motif Twickenham

ONE OF THE SHEEPBRIDGE ENGINEERING GROUP

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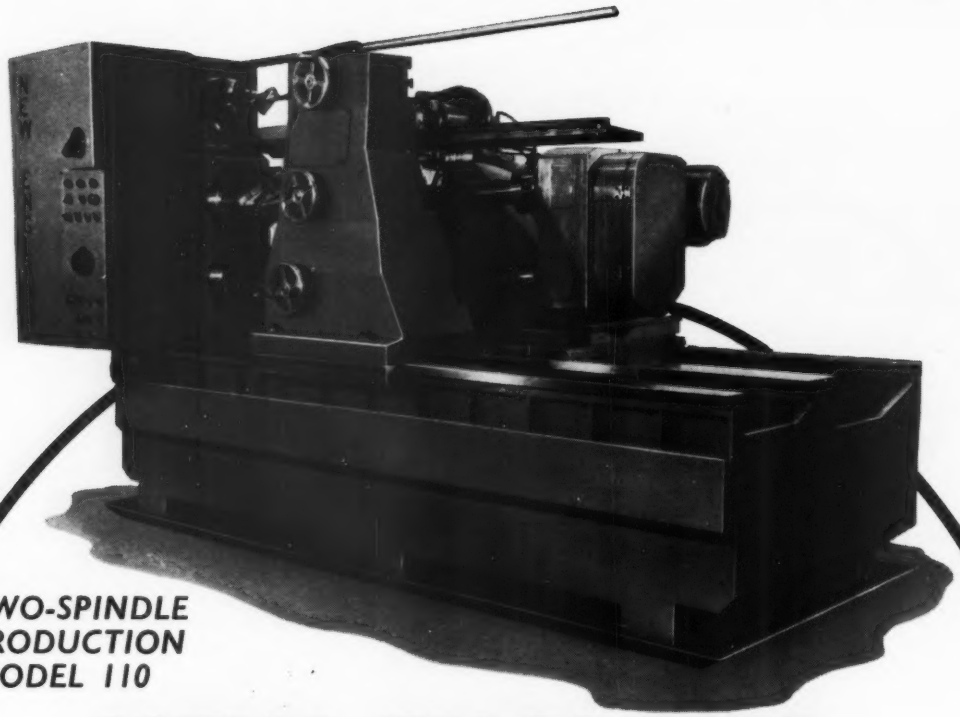


TWO-SPINDLE PRODUCTION MODEL 110

NEW ENGLAND
AIRFOIL MILLING MACHINE

This newly-designed two-spindle production airfoil milling machine is extremely large, rugged, heavy and a high speed machine, capable of handling the stock removal, in one cut, from either very rough forgings — or from bar stock — to the finished shape.

The machine is particularly applicable for economical production of medium and large steam turbine blades, industrial gas turbine blades and large compressor turbine blades for jet engines.
Capacity permits milling of blades up to 12 in. chord width by 60 in. length of foil shape.

Designed and manufactured by The New England Machine & Tool Company of Connecticut and sold by Pratt & Whitney Company for whom we are Sole Agents in the United Kingdom.

Also available Models 102—6 in. and 107—12 in. Electronic Airfoil Milling Machines.

For full details see Buck & Hickman Ltd. Machine Tool Catalogue, pages 61 - 62

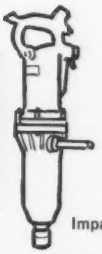
BUCK & HICKMAN LTD.

Machine Tools: Otterspool Way, Watford by-pass, Herts.

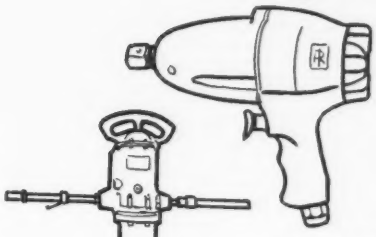
Head Office: P.O. Box No. 74, Whitechapel Road, London E.1.

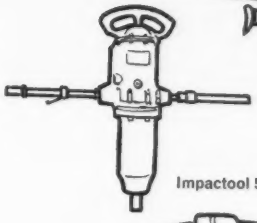
Branches: Alperton Birmingham, Bristol, Glasgow, Leeds, Manchester.

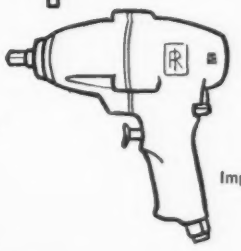
Ingersoll-Rand COMPANY LIMITED


Impactool 534

Impactool 518


Impactool 5100


Impactool 577


Impactool 5040

The IR range of Impactools has a tremendously wide application. It includes torque control models for work where precision is necessary and runs from ⅜" up to 2" bolt capacity. Low maintenance with maximum power, efficiency and manœuvrability. Reversible models are available and easily changed accessories and attachments give versatility for nut-running, drilling, reaming, tapping, screw driving and all jobs requiring rotary motion

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AT GEORGE ELLISON LTD

Town Radial Drilling Machines in the Birmingham Switchgear factory of George Ellison Ltd.— who first went to Town in 1934. They have since bought 36 drilling machines, keeping pace with latest improvements in design, and depend on them for maximum production rates and trouble-free service.

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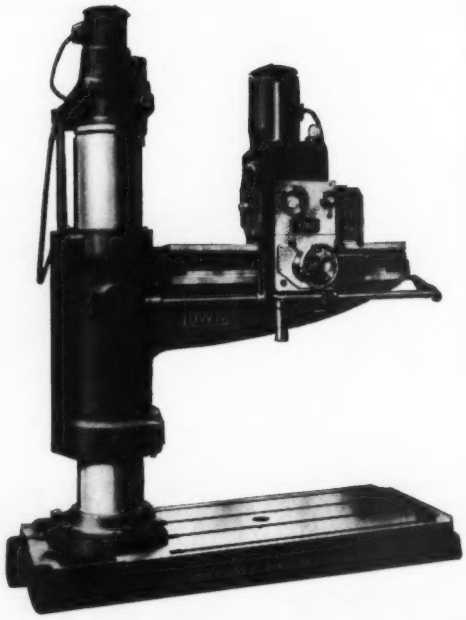

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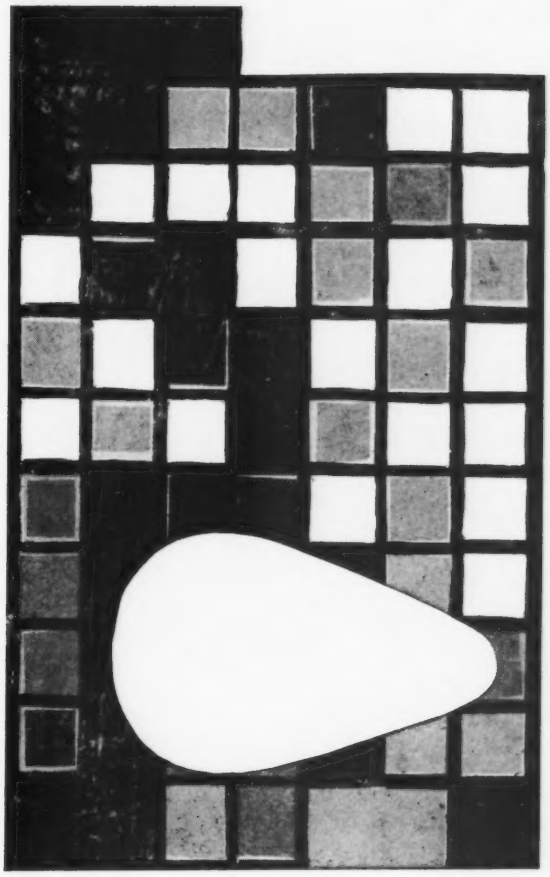

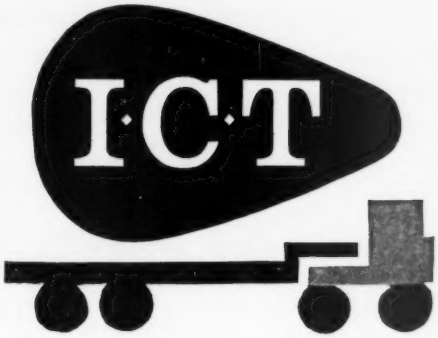

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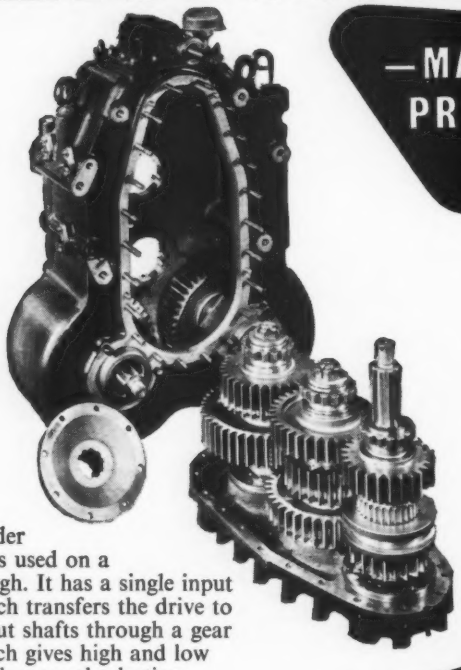
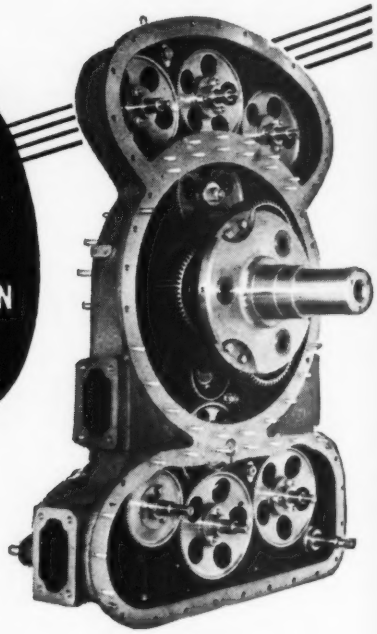
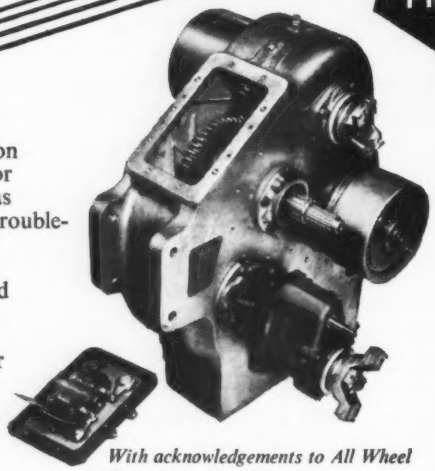


This divider gearbox is used on a snowplough. It has a single input shaft which transfers the drive to two output shafts through a gear train which gives high and low ratios with manual selection.

ACCURACY AND QUALITY ON A PRODUCTION BASIS



Used in 3 versions on "Michigan" Tractor Shovels, this box has proved completely trouble-free under the most arduous conditions. It has 4 forward and 4 reverse gears with manual high-low range selection. 2 or 4-wheel drive.



With acknowledgements to All Wheel Drive Ltd., Camberley, Surrey.

For use on an industrial gas turbine engine, this epicyclic gearbox reduces from 26,000 r.p.m. to an output speed of 3,000 r.p.m. in one step. There are nine auxiliary drives and a starter drive.

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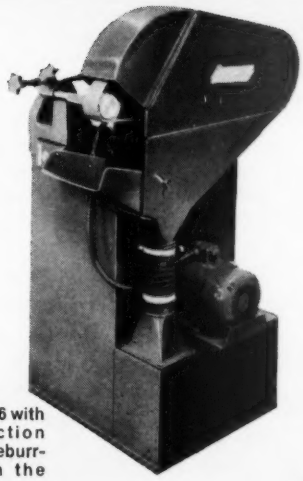

Model MA. 706 with Dust Extraction Pedestal for deburring right in the Machine Shop.

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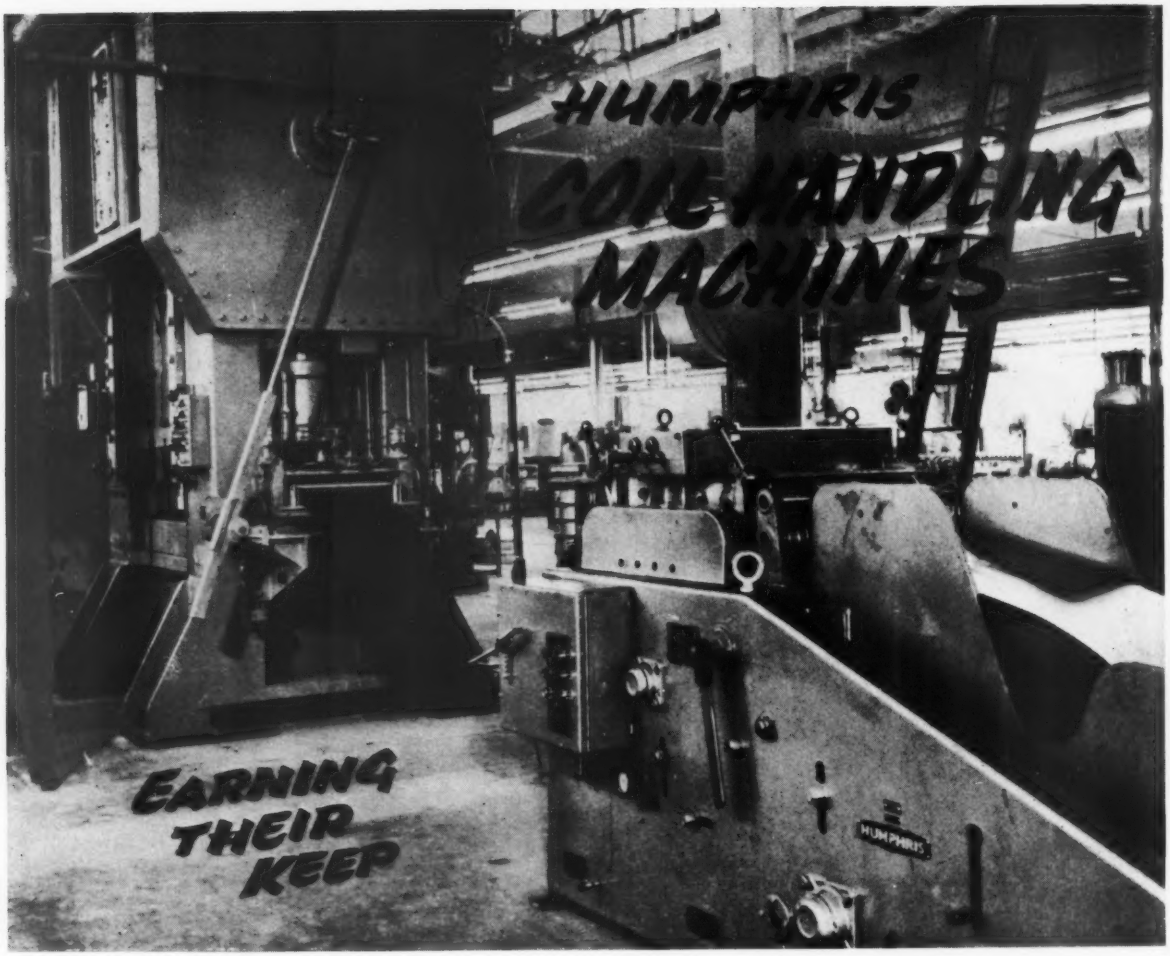
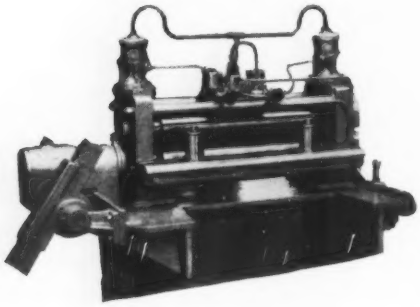
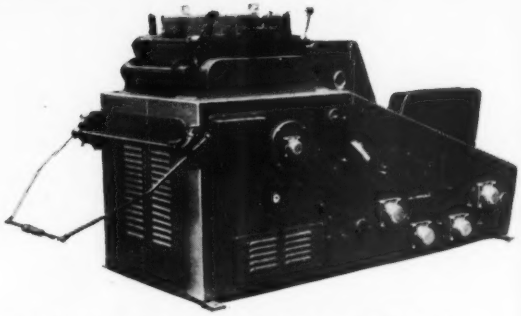


A heavy duty single roll feed teamed with a combined decoiling and levelling machine, handling 20 in. wide coiled strip at a large automotive accessory manufacturing plant in the Niagara Peninsula, Canada.





The Humphris standard range of decoilers, levellers and strip feeds are well-known and extensively used. Perhaps not so well-known is the fact that Humphris can supply virtually any size and shape of strip feed, strip leveller and decoiling machine. Whether your coils are light or heavy, thick or thin, narrow or wide, Humphris can offer you the necessary handling and feeding equipment.

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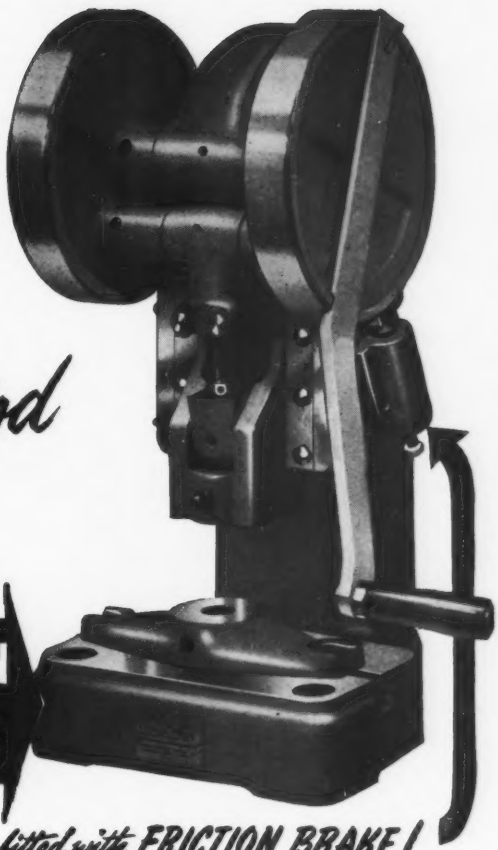

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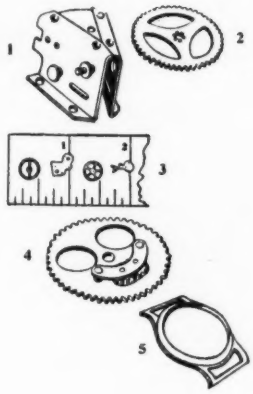

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2 Wheel stabbed to form keys. Single Operation.

3 Crop form after Auto turning. Pierce holes and form Location Studs. Pierce centre hole. Pierce two smaller holes and crop form at small end.

4 Hollow rivets on saddle fastened. Single Operation.

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Capacity	1 ton	2 ton
Throat to centre of Ram	$2\frac{1}{2}$″	$3\frac{1}{2}$″
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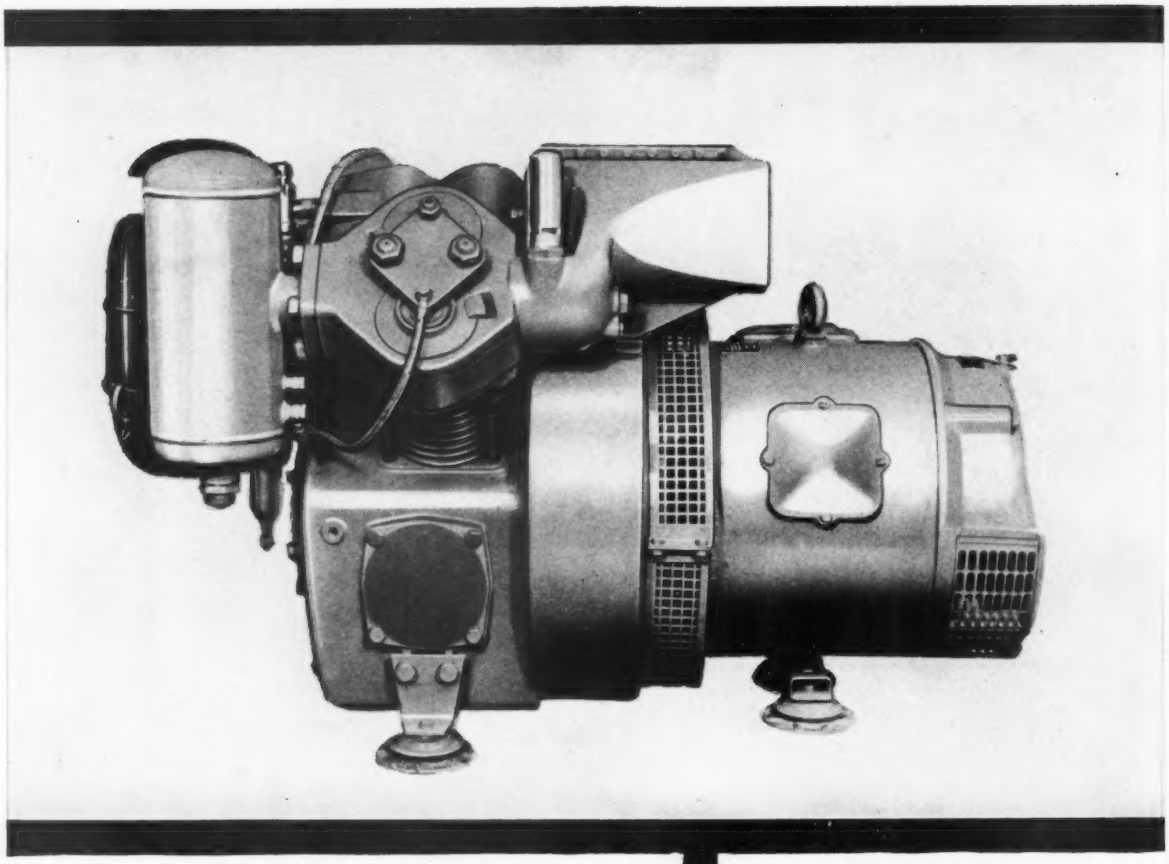

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Developed from the famous VT portable compressors, the Atlas Copco TT6 is a compact, heavy-duty machine for round-the-clock operation where there is a moderate but continuous demand for compressed air.

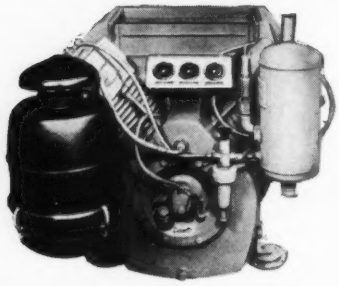
The compressor is a single-acting, two-stage machine with air-cooled cylinders and intercooler. It is built for a normal working pressure of 100 p.s.i. and has a free air delivery of 141 c.f.m.

NO FOUNDATIONS NEEDED. The TT6 and its electric drive motor are mounted on 'Metalastik' bonded rubber feet. This eliminates the need for foundations as the compressor can be placed directly onto concrete floors. The TT6 can also be moved from place to place as circumstances dictate.

Like the VT portables, the TT6 combines an outstanding power/weight ratio with a basically simple design which ensures reliable service and easy maintenance. The TT6 is a sound investment for medium-sized or small-but-growing companies.

AUTOMATIC CONTROL AVAILABLE. Available as an optional extra, the Atlas Copco Regulator allows the TT6 to be run with standard valve unloading system or as a fully automatic stop-and-start unit.

WRITE FOR THE LEAFLET Atlas Copco leaflet E1207-1 gives full details of the TT6. It is freely available on request from the address shown.



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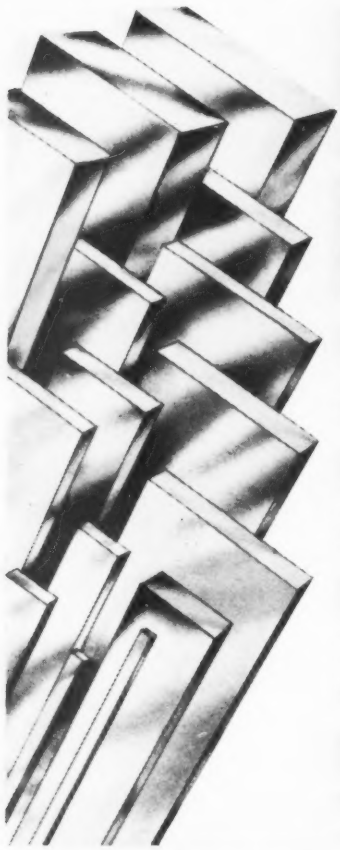

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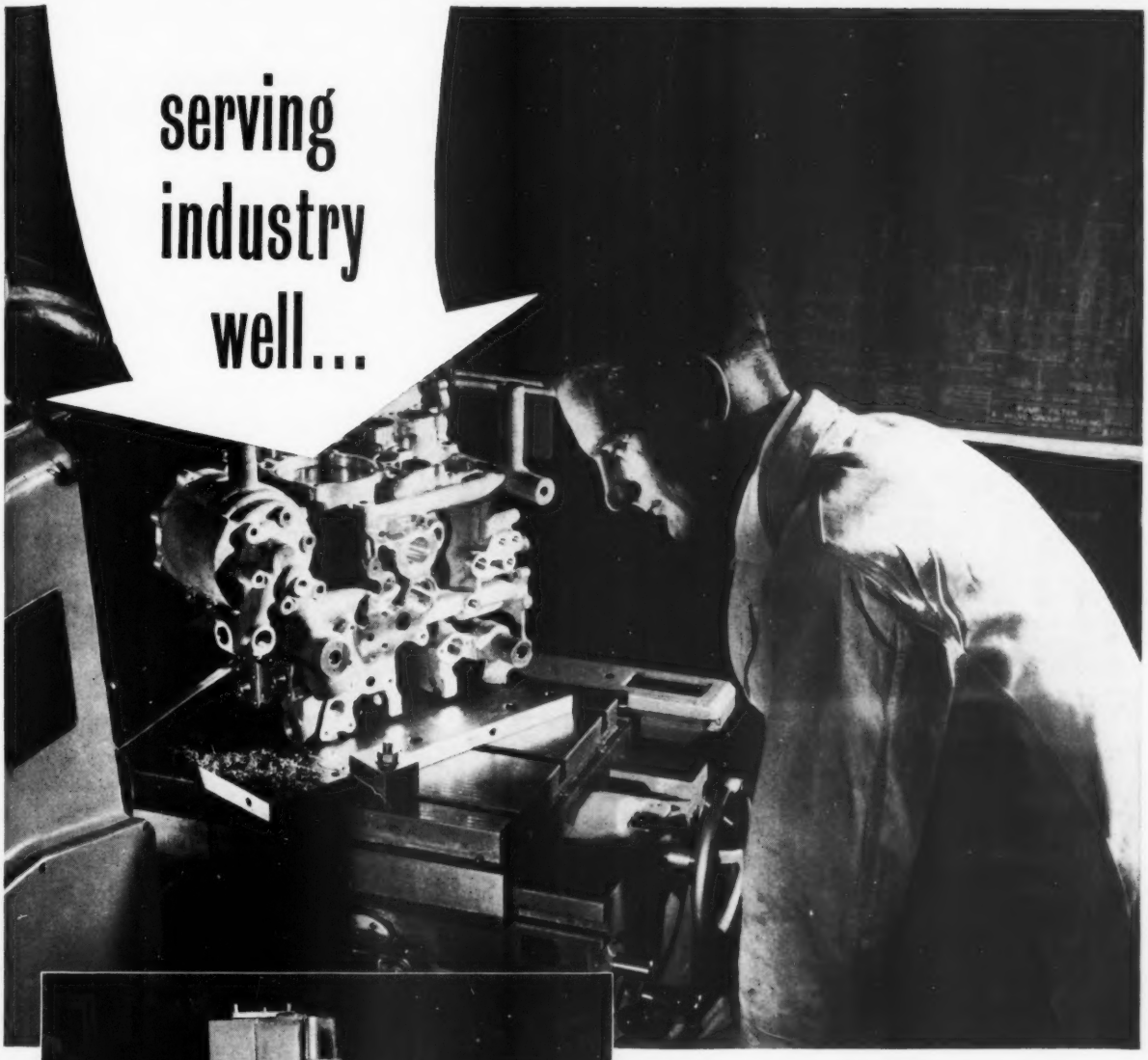

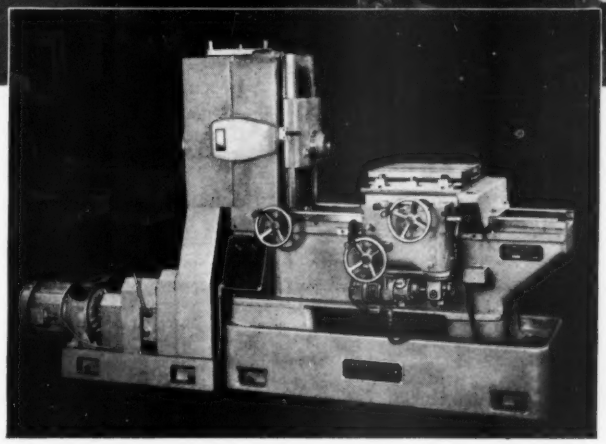

Above: A Kearns "S" type *OPTIMETRIC Horizontal Tool-Room Boring Machine machining the main body of an aircraft gas turbine fuel control unit at Dowty Fuel Systems Limited.

Photo courtesy: "Engineering"

The casting being machined has...

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* 20 recess chambers in the main bores
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Left: Recently supplied to Dowty Fuel Systems Limited, a Kearns "S" type *OPTIMETRIC Horizontal Tool-room Boring Machine, High Speed, Spindle Model.

*OPTIMETRIC *is the registered trade mark of Kearns System of optical measurement fitted as standard to all Kearns Horizontal Toolroom Boring Machines.*

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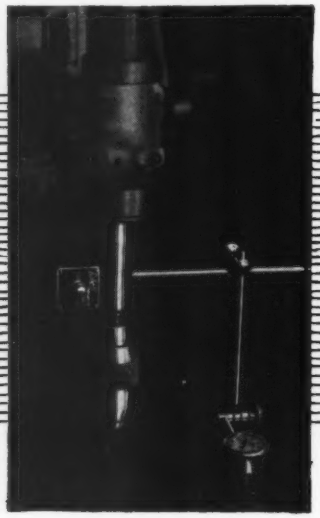

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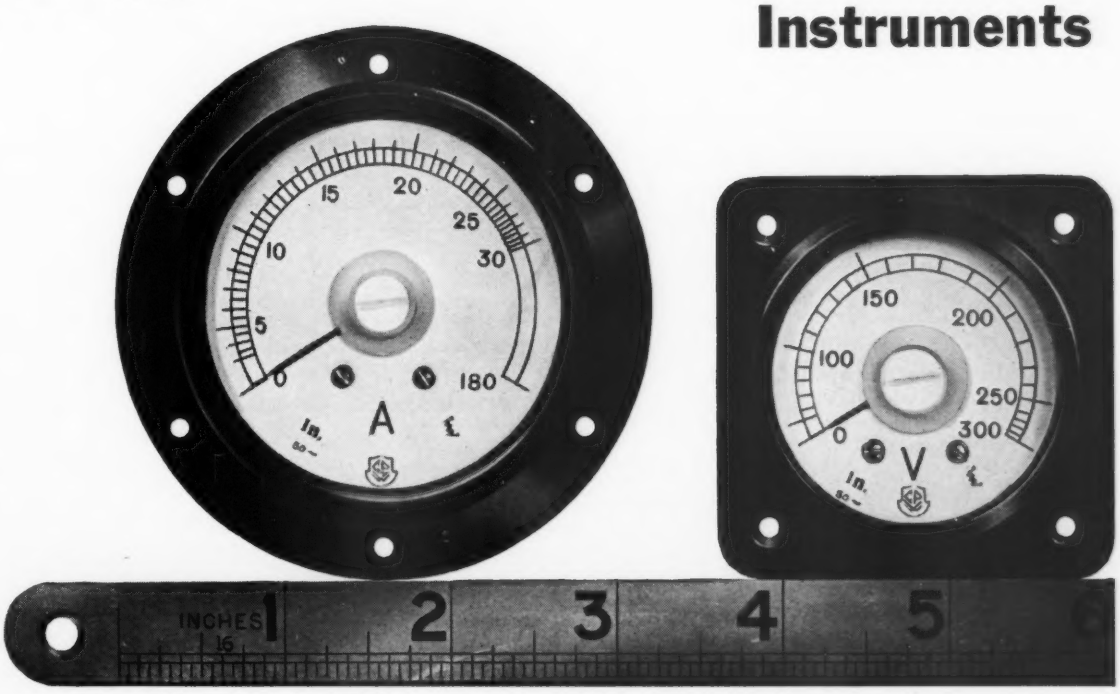

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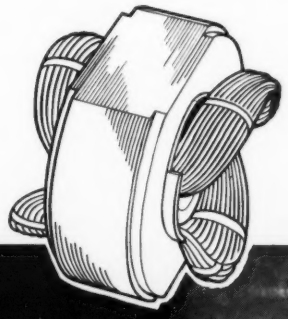

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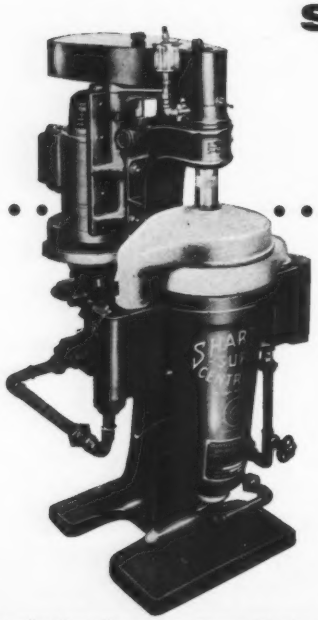

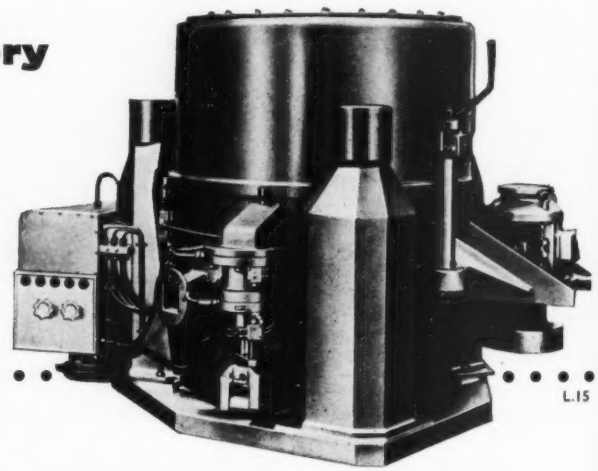

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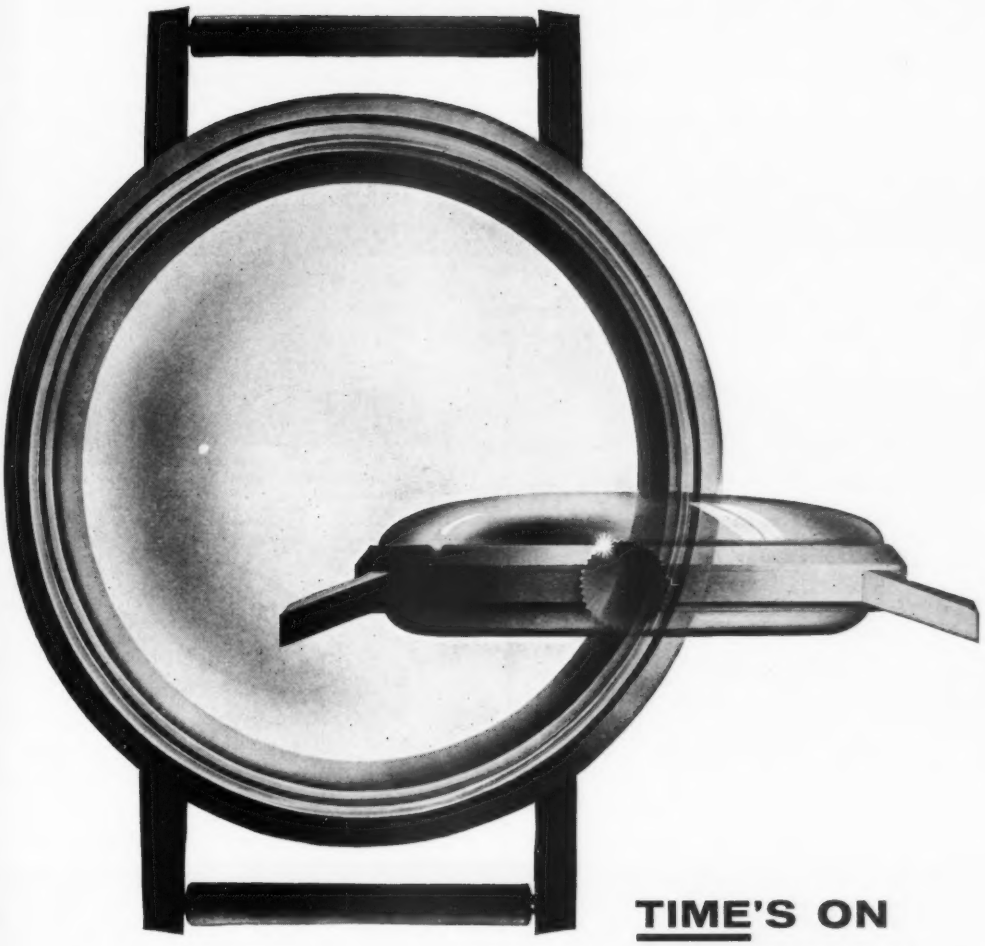

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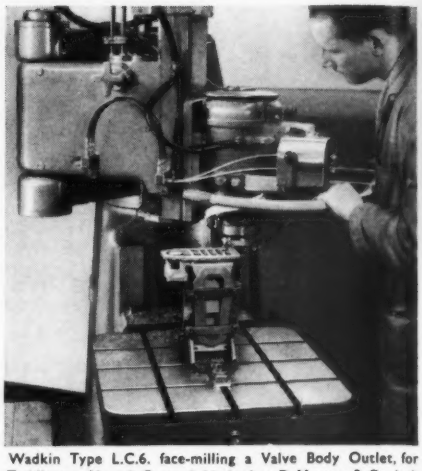
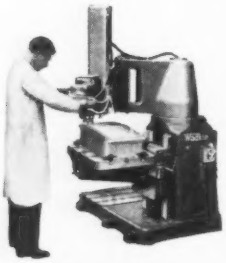
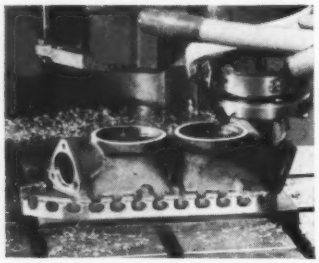


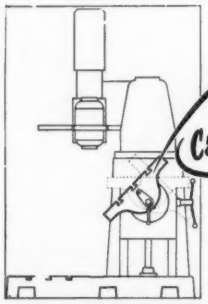
Wadkin Type L.C.6. face-milling a Valve Body Outlet, for Teddington Aircraft Controls Limited, at D. Merrett & Co. Ltd. of Tewkesbury.



Wadkin Articulated Arm Router L.C.6.

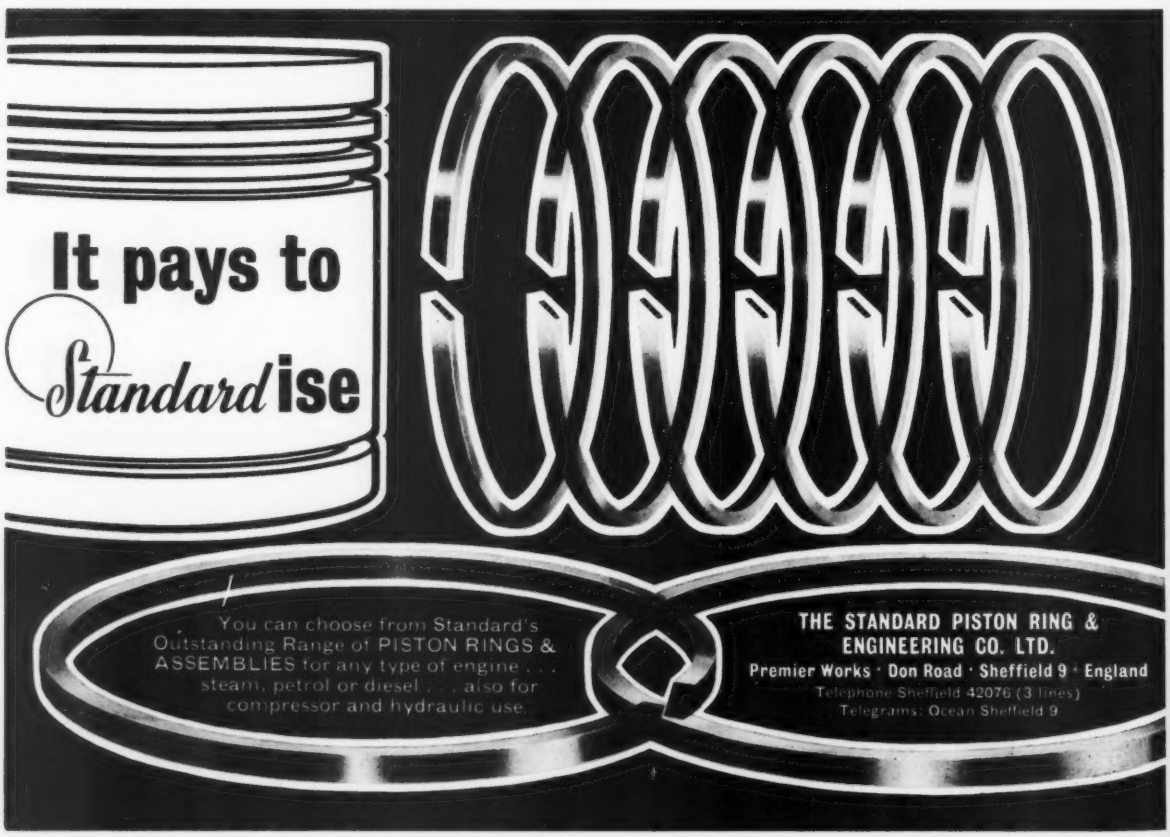


Face milling a Valve Body Component on a Wadkin Type L.C.6.



Unique Canting Table

This feature not previously associated with Routers enables table to be canted to the vertical on both the left an right-hand side.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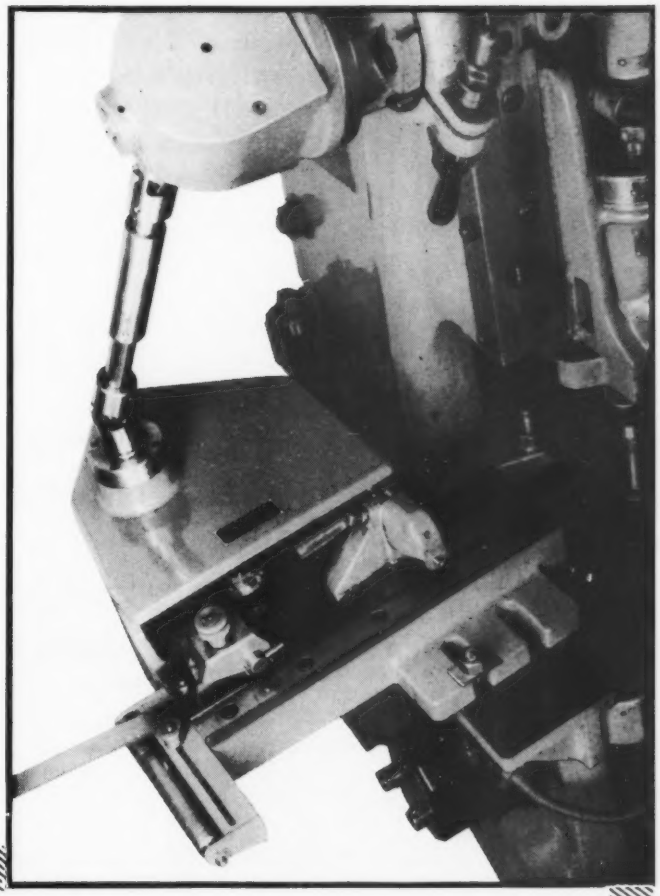

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* *Clark Equipment supplied regularly to the U.S.A.*
* *There's a pressing need for Clark feeds in every press shop!*

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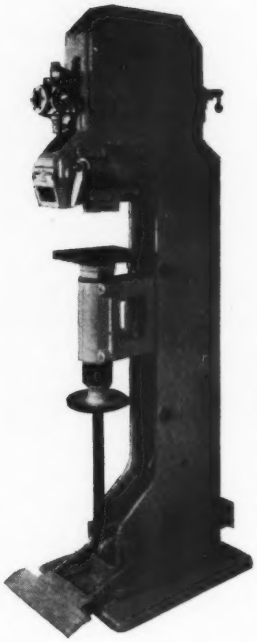
Telephone: West Drayton 2300

may we present

THE E.P. 34A
AIR-OPERATED MARKING MACHINE



This machine, the latest addition to the PRYOR range of marking equipment, simplifies and speeds up the marking of an extremely wide range of cylindrical and flat components. Air operation ensures exact uniformity of impression and reduces operator fatigue to a minimum. A full range of type holders, and geared roller-die carriers is available. Full details of this machine and of our hand-operated models will be sent on request.

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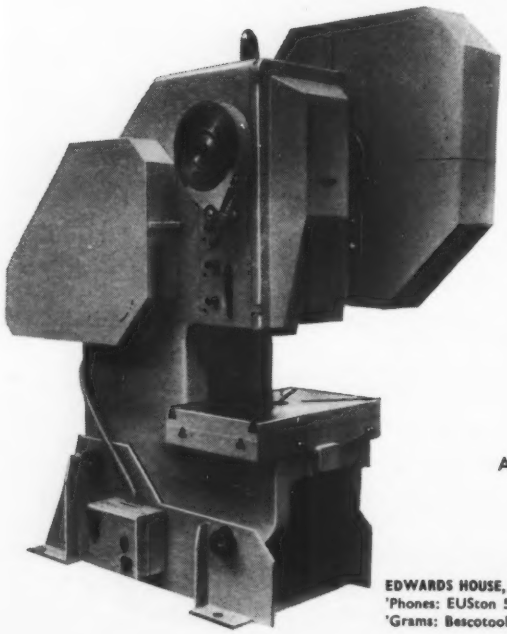
Select your press...

and with it, the necessary high performance for your work, from the nine different models in the 'LEN' range of

HEAVY-BUILD OPEN FRONTED INCLINABLE PRECISION PRESSES

each one an example of good engineering design and skilled workmanship.



These presses are unrivalled in adaptability to a wide variety of shearing, punching and drawing operations, and by employing automatic feeding attachments they are pre-eminently suitable for high speed quantity production, from coiled or strip material.

The 'LEN' range comprises the following models:

High speed presses type 'LENa' (ungeared)

Model	125/140	16/160	25/220*	40/250*
Pressure, tons	12.5	16	25	40
Adjustment of stroke, in.	$\frac{5}{16}$ to $2\frac{3}{4}$	$\frac{5}{16}$ to $2\frac{3}{4}$	$\frac{3}{8}$ to $3\frac{9}{16}$	$\frac{3}{8}$ to $3\frac{13}{16}$

Slow speed presses type 'LEN' (geared)

Model	25/220	40/250	63/280*	80/315	100/320
Pressure, tons	25	40	63	80	100
Adjustment of stroke, in.	$\frac{3}{8}$ to $3\frac{9}{16}$	$\frac{3}{8}$ to $3\frac{13}{16}$	$\frac{13}{16}$ to $4\frac{3}{16}$	$\frac{13}{16}$ to $4\frac{3}{8}$	$\frac{13}{16}$ to $5\frac{1}{8}$

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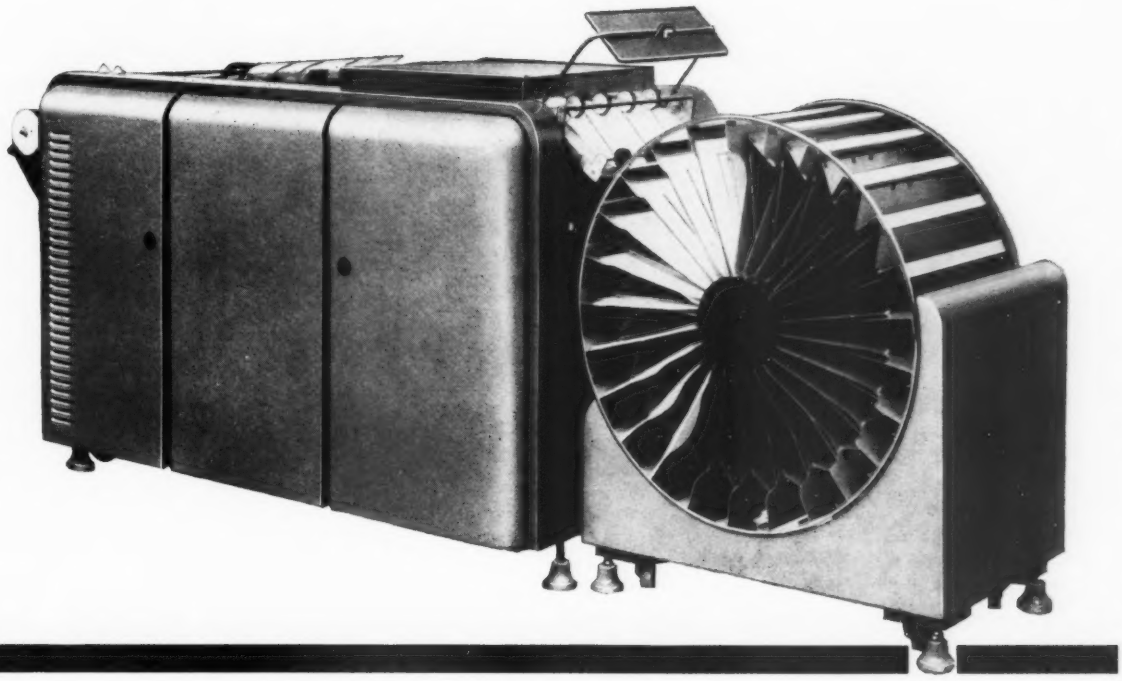
Plan for Expansion!



In every business there comes a time when paperwork—and the way it is handled—can make or mar expansion plans.

One AZOFLEX Model 150 Automatic photoprinting machine, operated by one girl, can produce 10,000 dyeline copies of business documents in every working day. You can use this machine to catch up with your Company's need for more invoices and purchase order sets, the multi-reproduction of computer outputs, and forms for general business systems.

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AZOFLEX machines need no ducting, are fume and glare-free in operation. Inexperienced staff quickly grasp the simple details of AZOFLEX machine operation.

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Your company might benefit . . .
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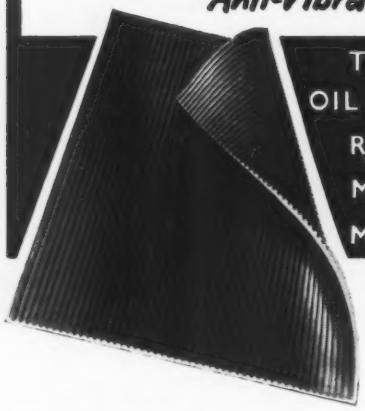

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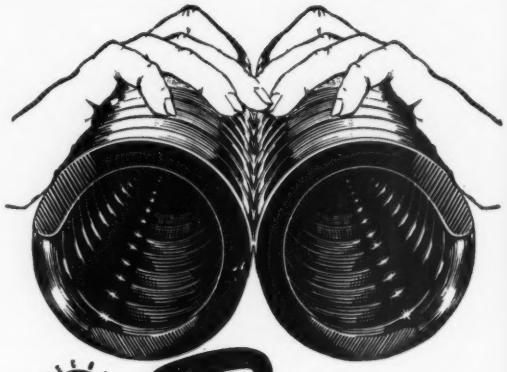

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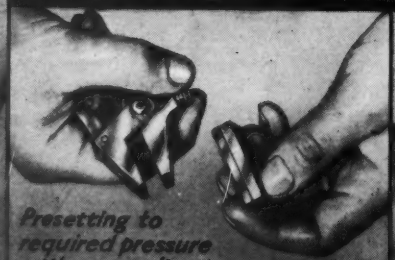
- *Can be used as fixture or as hand tool*
- *Simple to use yet so sure in its action*



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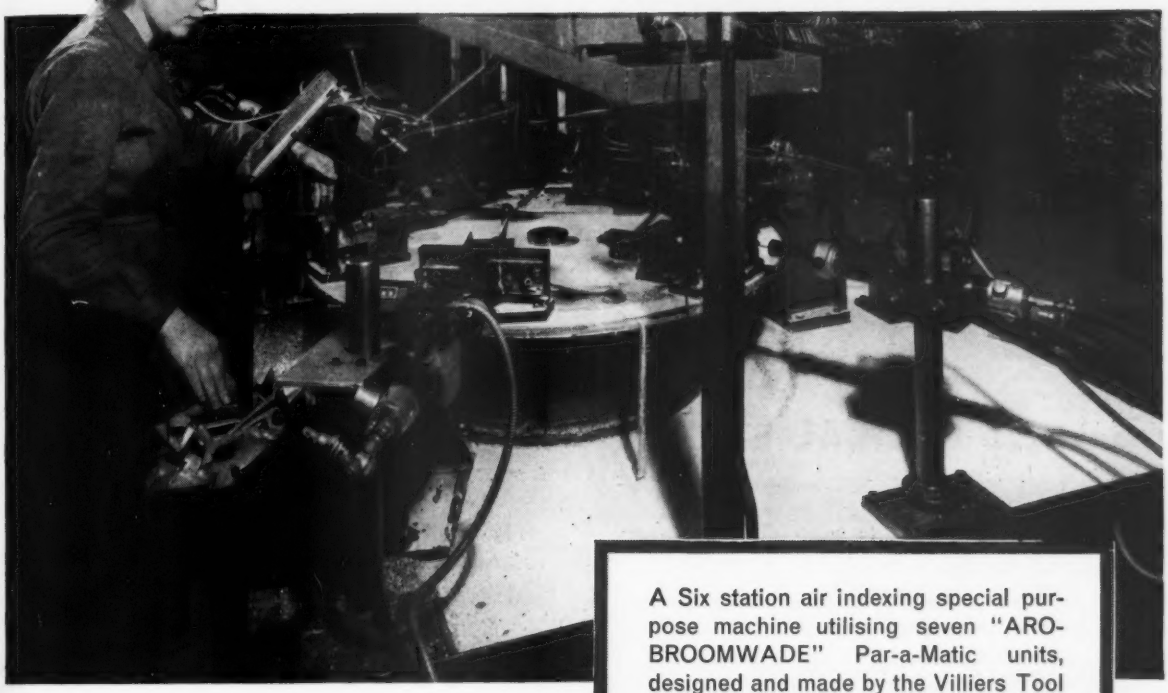
...with "ARO-BROOMWADE" Par-a-Matics



A Six station air indexing special purpose machine utilising seven "ARO-BROOMWADE" Par-a-Matic units, designed and made by the Villiers Tool Developments Ltd. of Wednesfield, Staffs. for Messrs. Fry's Diecastings Ltd.

This machine carries out the following sequence of operations at a *production rate of 150 per hour. Previous methods produced only 200 per day.*

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2nd Station—Tap 2 holes 10 u.n.f.

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4th Station—Tap 1 hole 6 BA.

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6th Station—Unload fixture and load fresh component.

Special note should be made of the 2 spindle drilling head attached to the PAR-A-MATIC for drilling the 2 close spaced holes at Station No. 3.

Photograph by courtesy of Messrs. Fry's Diecastings Ltd.

From 200 per *day* to 150 per *hour*—this is the remarkable increase that "ARO-BROOMWADE" Par-a-Matics have effected in the production of automobile door handles for Messrs. Fry's Diecastings Ltd.

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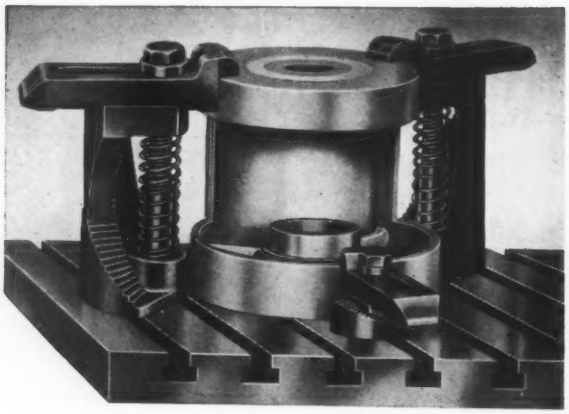

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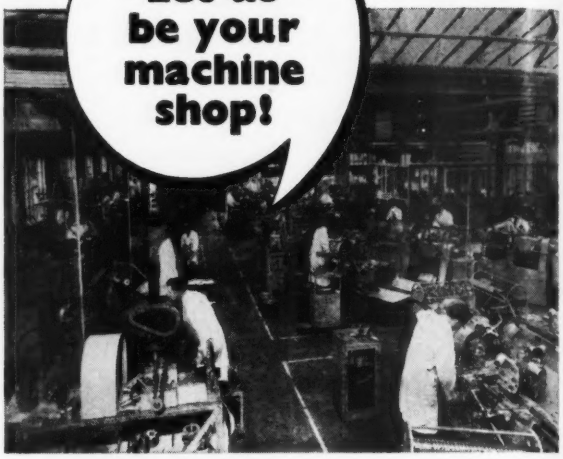

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Compact design reduces to a minimum, distance from drill head to machine spindle, whilst careful selection of material ensures an extremely efficient light weight head.

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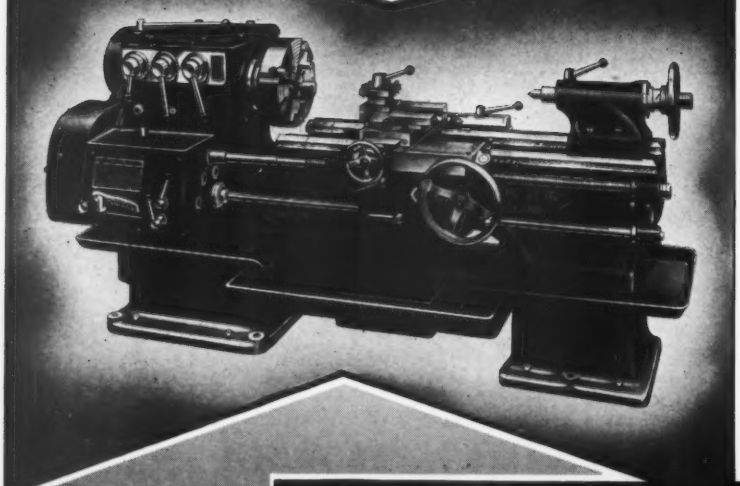

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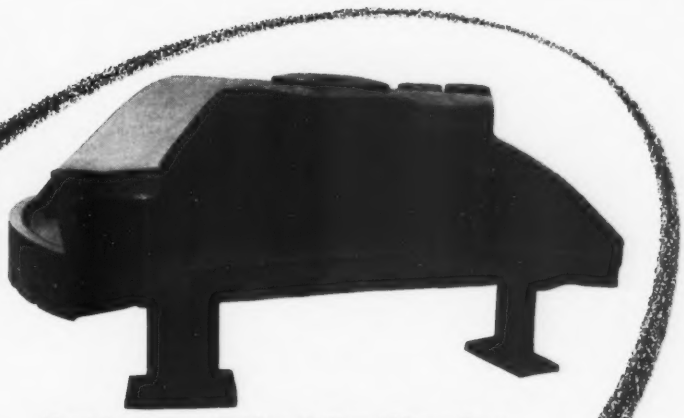

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INDEX TO ADVERTISEMENTS

Please note that all advertisement pages are prefixed with the letter "A"

	Page
Adcock & Shipley, Ltd.	A21
Adrema, Ltd.	A66
Aircraft-Marine Products (Great Britain), Ltd.	A23
Airmec, Ltd.	A5
Alexander, Geo., Machinery, Ltd.	—
Allen, Edgar, & Co. Ltd.	A4
Allspeeds, Ltd.	A67
Arc Manufacturing Co. Ltd.	—
Archdale, James, & Co. Ltd.	A84
Asquith, William, Ltd.	A56
Associated Electrical Industries, Ltd.	A63
Atlas Copco (Great Britain), Ltd.	A96
Automotive Engineering, Ltd.	A87
B.S.A. Tools, Ltd.	A57
Barber & Colman, Ltd.	—
Benton & Stone, Ltd.	A22, A60
Birmingham Aluminium Casting (1903) Co. Ltd.	—
Birmingham Tool & Gauge Co. Ltd.	A32
Bishop Eaves & Sons, Ltd.	A13
Bliss, E. W. (England), Ltd.	A69
Block & Anderson, Ltd.	A10
Borg-Warner, Ltd.	A14
Bound Brook Bearings, Ltd.	A42
Braby, Frederick, & Co. Ltd.	A6
Brauer, F., Ltd.	—
British Aero Components, Ltd.	A29
British Industrial Eng. Co. (Staffs.), Ltd.	—
British MonoRail, Ltd.	—
British Oxygen Co. Ltd.	—
Brockhouse, J., & Co. Ltd.	A102
Broom & Wade, Ltd.	A111
Brown, David, Corpn. (Sales), Ltd., The	A81
Buck & Hickman, Ltd.	A88
Bullows, Alfred, & Sons, Ltd.	A79
Burton Griffiths & Co. Ltd.	A57
Butler Machine Tool Co. Ltd., The	—
Canning, W., & Co. Ltd.	A3
Carborundum Co. Ltd., The	—
Castrol Industrial Ltd.	—
Carrier Engineering Co. Ltd.	—
Centec Machine Tools, Ltd.	—
Centrax, Ltd.	A92
Churchill, Charles, & Co. Ltd.	A1
Churchill Machine Tool Co. Ltd.	—
Ciba (A.R.L.), Ltd.	A74
Cincinnati Milling Machines, Ltd.	A8, A9
Clark's Press Equipment, Ltd.	A107
Colt Ventilation, Ltd.	A34
Cooper & Co. (Birmingham), Ltd.	—
Concentric (Engineering), Ltd.	A82
Coventry Climax Engines, Ltd.	*Outside Back Cover*
Cowlishaw, Walker & Co. Ltd.	A15
Crawford Collets, Ltd.	—
Crompton Parkinson, Ltd. (Instruments)	A101
Crosland, William, Ltd.	A102
Crowthorn Engineering Co. Ltd.	A114
D.M.M. (Machinery), Ltd.	A18
Davis, Stuart, Ltd.	A27
Dawson Bros., Ltd.	—
Dean Smith & Grace, Ltd.	A64
Denham's Engineering Co. Ltd.	A40, A41
Dowding & Doll, Ltd.	A86
Drummond-Asquith, Ltd.	—
Drummond Bros., Ltd.	A55
E.N.V. Engineering Co. Ltd.	—
Edwards, F. J., Ltd.	A108
Efco Furnaces, Ltd.	—
Elcontrol, Ltd.	A39
Electrical Development Association	A83
Elliott, B. (Machinery), Ltd.	—
English Electric Co. Ltd., The	—
English Numbering Machines, Ltd.	A76
English Steel Tool Corpn., Ltd.	—
Exors. of James Mills, Ltd.	A2
Firth, Thos., & Brown, John, Ltd.	A68
Flame Hardeners, Ltd.	—
Fletcher Miller, Ltd.	A36
Ford Motor Co. Ltd.	—
Forgings & Presswork, Ltd.	—
G.W.B. Furnaces, Ltd.	—
Garner, Geo., & Sons, Ltd.	—
Gas Council, The	—
Gear Grinding Co. Ltd.	—
Gosheron, John, & Co. Ltd.	A22
Goulder, J., & Sons, Ltd.	—
Guest, Keen & Nettlefolds (Midlands), Ltd.	—
Harvey, G. A., Co. (London), Ltd.	—
Heenan & Froude, Ltd.	—
Herbert, Alfred, Ltd.	A103
Hey Engineering Co. Ltd.	A112
Honeywell Controls Ltd. (Micro Switch Division)	A70
Hordern, Mason & Edwards, Ltd.	—
Humphris & Sons, Ltd.	A94
Hymatic Engineering Co. Ltd., The	A80
Ilford, Ltd.	A109
Industrial Diamond Information Bureau	A105
Ingersoll-Rand Co. Ltd.	A89
Ingham, Robert, Clark & Co.	A49
International Computers and Tabulators, Ltd.	A91
Isopad, Ltd.	—
Jacobs Manufacturing Co. Ltd., The	A52
Johansson, C. E., Ltd.	A11
Jones, A. A., & Shipman, Ltd.	A26
Kane, Douglas, Sealants, Ltd.	A71
Kearney & Trecker—C.V.A., Ltd.	A113
Kearns, H. W., & Co. Ltd.	A99
King, Geo. W., Ltd.	A7
Kitchen & Wade, Ltd.	A78
Landis Lund, Ltd.	A17
Lang, John, & Sons, Ltd.	—
Lapointe Machine Tool Co. Ltd., The	—
Ley's Malleable Castings Co. Ltd.	—
Leytonstone Jig & Tool Co. Ltd.	—
Lincoln Electric Co. Ltd., The	A75
Lloyd, Richard, Ltd.	—
Lockheed Hydraulic Brake Co. Ltd.	—
Lockheed Precision Products, Ltd.	—
Londex, Ltd.	—
Macready's Metal Co. Ltd.	A98
Markland Scowcroft, Ltd.	A37
Marsden & Shiers, Ltd.	A112
Maxam Power, Ltd.	A24, A25
Metalock (Britain), Ltd.	A115
Midland Silicones, Ltd.	—
Mobil Oil Co. Ltd.	A51
Modern Machine Tools, Ltd.	A22
Morris, B. O., Ltd.	A93
Morse Chain	A14
National Industrial Fuel Efficiency Service	A100
Neill, James, & Co. (Sheffield), Ltd.	A100
Newall Group Sales, Ltd.	A53
Newman Industries, Ltd.	—
Norgren, C. A., Ltd.	—
Norwood Steel Equipment, Ltd.	A16
Optical Measuring Tools, Ltd.	A53
Ormerod Shapers, Ltd.	—
Osborn, Samuel, & Co. Ltd.	—
Ottermill Switchgear, Ltd.	—
Park Gate Iron & Steel Co. Ltd.	—
Parkinson Cowan Measurement	A30, A31
Parkinson, J., & Son (Shipley), Ltd.	A58
Parramore, F., & Son (1924), Ltd.	A114
Payne Products International, Ltd.	—
Peak Engineering Co. Ltd.	—
Pels, Henry & Co. Ltd.	—
Phosphor Bronze, Ltd.	—
Powell & Co.	—
Power Petroleum Co. Ltd.	A45
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Pryor, Edward, & Son, Ltd.	A108
Pultra, Ltd.	—
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Ratcliffe, F. S. (Rochdale), Ltd.	A110
Reavell & Co. Ltd.	—
Renault Machine Tools (U.K.), Ltd.	—
Renold Chains, Ltd.	A77
Rockwell Machine Tool Co. Ltd.	A35, A112
Rowen-Arc	—
Rubert & Co. Ltd.	—
Rubery, Owen Co. Ltd.	—
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Ryder, Thos., & Son, Ltd.	—
Sharples Centrifuges, Ltd.	A104
Sheffield Twist Drill & Steel Co. Ltd.	—
Shell-Mex & B.P., Ltd.	A72, A73
Siemens-Schuckert (G.B.), Ltd.	—
Smit, J. K., & Sons, Diamond Tools Ltd.	A97
Smart & Brown (Machine Tools), Ltd.	A95
Snow, & Co. Ltd.	—
Solex (Gauges), Ltd.	—
Speed Tools, Ltd.	A110
Speedright Gauge & Tool Coventry	—
Standard Piston Ring & Engineering Co. Ltd.	A106
Standard Telephones & Cables, Ltd.	—
Stein Atkinson Vickers Hydraulics, Ltd.	A19
Stephens Belting Co. Ltd.	A36
Stone, J. & Co. (Deptford), Ltd.	A44
Sunbeam Anti-Corrosives, Ltd.	—
Super Oil Seals & Gaskets, Ltd.	—
Swift, Geo., & Sons, Ltd.	A54
Sykes Machine Tool Co. Ltd., The	—
Sykes, W. E., Ltd.	—
Talbot Tool Co. Ltd., The	*Inside Back Cover*
Teddington Industrial Equipment, Ltd.	—
Terry, Herbert, & Sons, Ltd.	—
Thompson, John, Motor Pressings, Ltd.	—
Tilghman's Ltd.	—
Town, Frederick, & Sons, Ltd.	A90
Tufnol, Ltd.	—
Tyer & Co. Ltd.	A104
Uni-Tubes, Ltd.	—
United Dominions Trust (Commercial), Ltd.	A50
Universal Tools, Ltd.	—
Vacu-Blast, Ltd.	—
Vaughan, Associates, Ltd.	A85
Vaughan, Edgar, & Co. Ltd.	—
Vickers-Armstrongs (Engineers), Ltd.	A33
Vulcascot (Gt. Britain), Ltd.	A110
Ward, H. W., & Co. Ltd.	A59
Ward, Thos. W., Ltd.	—
Wadkin, Ltd.	A106
Weatherley Oilgear, Ltd.	A10
Webster & Bennett, Ltd.	A20
West, Allen, & Co. Ltd.	—
Whiffen & Sons, Ltd.	A38
Wickman, Ltd.	A48, A61
Wild-Barfield Electrical Furnaces, Ltd.	—
Wilkins & Mitchell, Ltd.	—
Woodhouse & Mitchell	—
Wolverhampton Die Casting Co. Ltd.	A43
Youngman, W. C., Ltd.	A46, A47, A62

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Page

—
—
—
A45
A28
—
—
A65
A108
—
A12
A110
—
—
A77
A112
—
—
—
A98
—
A104
—
2, A73
—
A97
A95
—
A110
—
A106
—
A19
A36
A44
—
—
A54
—
—
Cover
—
—
—
—
A90
—
A104
—
A50
—
—
A85
—
A33
A110
A59
—
A106
A10
A20
—
A38
3, A61
—
—
—
A43
7, A62

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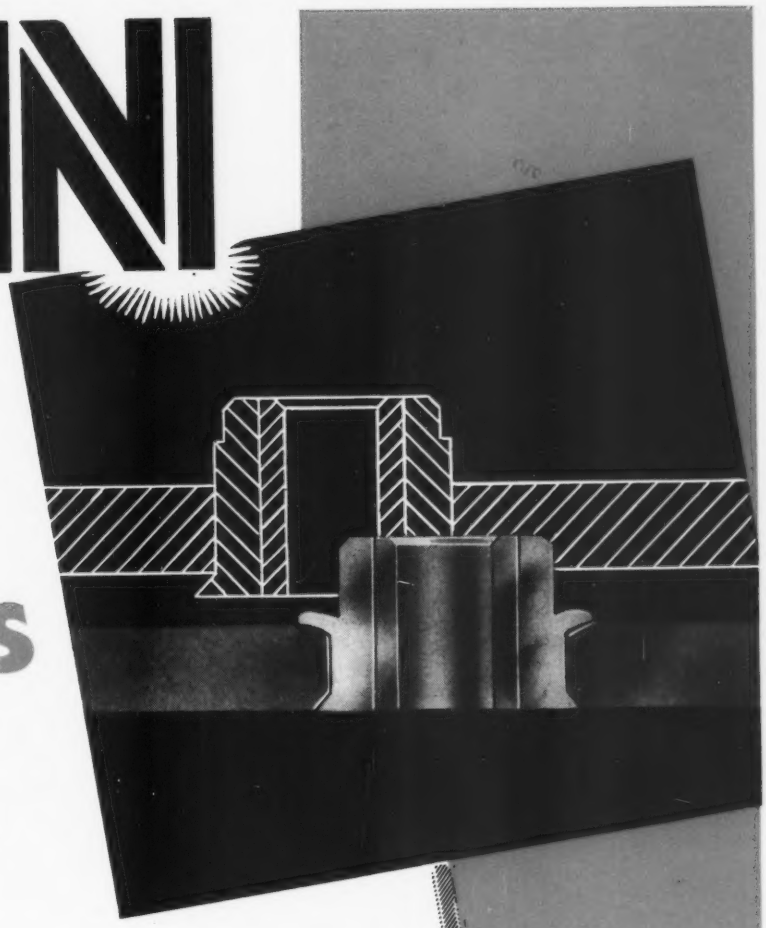

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